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DANIELS AND ALCOCK

PART II

DISEASES DUE TO THE METAZOA

SECOND EDITION

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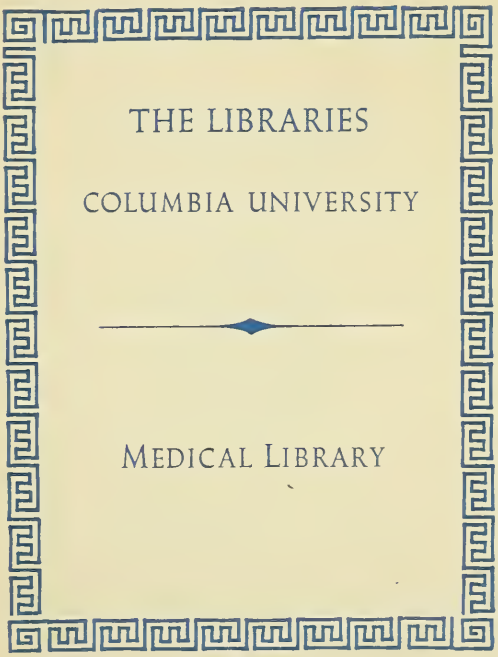

TROPICAL MEDICINE
AND
HYGIENE

BY

C. W. DANIELS

M.B.Cantab., F.R.C.P.Lond.

Lecturer on Tropical Diseases, London School of Tropical Medicine; London Hospital; London (Royal Free) School of Medicine for Women; Physician, Albert Dock Hospital, Seamen's Hospital Society; formerly Director London School of Tropical Medicine; Director Institute for Medical Research, Federated Malay States; Member of Royal Society Malaria Commission, and in the British Guiana and Fiji Colonial Medical Services

WITH A CHAPTER ON SNAKES

BY

A. ALCOCK

C.I.E., M.B., F.R.S., Lt.-Col. I.M.S. (retd.)

IN THREE PARTS, WITH COLOURED AND OTHER ILLUSTRATIONS

PART II

DISEASES DUE TO THE METAZOA

SECOND EDITION

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TROPICAL
MEDICINE AND HYGIENE

PART II

Diseases due to the Metazoa

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PREFACE TO THE SECOND EDITION.

During the last three years numerous advances in our knowledge of the diseases dealt with in this part have taken place. These as far as possible are included in this edition.

I have to thank Dr. H. B. Newham, now Director of the London School of Tropical Medicine, for aid in revision of proofs and for many valuable suggestions.

C. W. D.

PREFACE TO THE FIRST EDITION.

In this, as in the other volumes, the aim of the authors is to provide a concise description of the diseases due to various kinds of parasites, and of the manner in which they spread, and the rationale of the preventive measures advocated.

A certain amount of systematic zoology is necessary for the identification of the various parasites, but the books are in no sense systematic works on Protozoology, Helminthology, or Entomology.

Systematic works on these important subjects will, it is hoped, be written by medical men who have specially studied these branches of zoology, adapted to the requirements of the medical and veterinary professions.

The grouping of diseases according to the class of parasites has in some cases disadvantages. This is specially so in the intestinal disorders with dysenteric symptoms. Such symptoms may be due to protozoa, helminths, or bacteria. Whilst they are briefly considered in connection with the class of parasite that causes them, the full consideration and comparison will be made in Part III, when the different forms can be contrasted.

Major Wilkinson, unfortunately, was only able to take part in the preliminary consideration of the subjects treated of in this volume, owing to his absence from the country, and therefore cannot be held responsible for the contents of this book.

C. W. D.

Tropical Medicine and Hygiene

PART II.—DISEASES DUE TO METAZOA.

CHAPTER I.

INTRODUCTORY.

THE *Metazoa* include many forms of animal life parasitic in man. Some of these parasites cause definite diseases which may lead to death or disablement. They serve as good examples of the various kinds of parasitism. Thus the filariæ are examples of metazoa parasitic, in vertebrates or invertebrates, during their entire existence. Such parasites for their continued reproduction and multiplication require the presence not only of human beings but also of a suitable intermediate carrier. These carriers may be insects such as mosquitoes, or biting flies, or crustaceans such as cyclops. Molluscs also are carriers, as some of the trematodes develop in them. Meteorological conditions must be such that both growth of the parasite in these cold-blooded hosts will take place, and also that conditions favourable for the life and growth of these invertebrate hosts exist, otherwise the continued propagation of the parasite could not take place. When the parasites have been introduced into the warm-blooded host they may continue their existence indefinitely.

Other parasites of man, as some of the tapeworms, are parasitic during different phases of their existence in mammals of different species, and in the case of such parasites meteorological conditions are of little importance. Proximity of man to the other mammals is the main condition required in some cases, in others it is a question of one animal consuming the flesh of the others.

Other parasites, as the *Ascaris lumbricoides*, are parasitic in man only, and though their eggs or embryos are passed externally, development is limited until they are reintroduced into man. Others, again, as the Ankylostoma, develop to a considerable extent as free-living larvæ. This development is dependent on temperature and other simple meteorological conditions, but the completion of the development requires that such larvæ should again have access to man.

A knowledge of the different modes of development of different species is a necessary preliminary to the understanding of the measures required for the prevention of infection and therefore of the diseases caused by these parasites.

Forms of Parasites.—Parasitism may be permanent, and in that case bodily change of the parasite results. Even with ectoparasites, which do not live in the interior of the body, special modifications occur, for instance, wings are often absent or rudimentary, as in the fleas, sheep-keds, and pediculi. The claws (ungues), on the other hand, are frequently exceptionally well developed.

With internal parasites still further modifications occur, so that they become quite unsuited for external life. Many of these cease to be actively motile during some periods of their parasitic life; in others the alimentary canal is rudimentary or lost, as in the *Filaria medinensis*, or Guinea-worm. Hermaphroditism is common in parasites, though not limited to them.

In many cases the males die early, and the females, after fertilization, become little more than living receptacles of ova. In such instances every vital function is subordinate to the development of the fertilized ova.

It is not uncommon for parasites to feed on waste products of their host or on superfluous food; such parasites are known as commensal parasites. The bird-lice, for instance, live merely on epithelial *débris*, and, therefore, may be actually beneficial to their hosts.

Parasites may be confined to one class of host, and

are then said to be specific to that class. Thus *Tænia solium* and *T. saginata*, in their adult condition, are specific to man.

Some parasites are common to several classes of hosts; these hosts, as a rule, are related fairly closely, but not invariably so. *Trichina spiralis* is common to man, pigs and rats, as well as to many other animals.

Parasites that are very abundant in some hosts are found occasionally in other animals. When this occurrence is exceptional the parasites are said to be incidental or accidental. Thus *Fasciola hepatica*, so common in sheep and cattle, may be an incidental parasite of man.

Effects of Parasites on their Hosts.—The diseases due to animal parasites may be the direct results of injuries—mechanical effects—caused by the parasites, their eggs or embryos; or they may be caused by a poison—toxin—elaborated by the parasites themselves; or they may cause conditions which favour the introduction of other parasites, animal or vegetable, which set up definite diseases. Frequently both effects are produced and play a part in the special characters of the disease which results from their presence.

Injurious Non-parasitic Metazoa.—Metazoa not necessarily parasites in a strict sense are, in some cases, injurious to man. Many of the insects attack man, and by their bites or stings produce effects, either trivial or merely local, as in the case of mosquitoes or sandflies, or more severe, as in some of the Hymenoptera, such as wasps and hornets. Ticks, spiders and scorpions may similarly cause local lesions or general poisoning when they attack men.

Metazoa as Carriers of Parasites.—Some of the Arthropoda, such as mosquitoes, tsetse-flies and ticks, are the active and essential agents in the transmission from man to man of dangerous parasitic protozoa, as those of malaria, relapsing fever and sleeping sickness; or metazoa, such as those causing elephantiasis and other forms of filariasis.

Where arthropoda are essential transmitting agents, the parasites, whether protozoa or metazoa, must develop to a certain extent in them before being capable of further development in man.

In other cases insects are important as mechanical carriers,—"porters"—of disease germs, usually bacteria. Then they are but the mechanical means of conveying organisms present in excreta to food used for human consumption. Typhoid fever, cholera, &c., may be conveyed in this way. In other cases, such as plague, the insects—in this instance fleas—feed on an infected animal, then on others, which they infect with the germs derived from the first. In these insects, though multiplication of the germs may take place, they are not essential for inoculation, and the germs can be conveyed from man to man in other ways under natural conditions.

Aquatic larvæ may acquire parasites, and in their adult stage, as—imagines—distribute them.

Venomous Metazoa.—Many of the insects form definite poisons or venoms, and these are then described as venomous. The term is more usually applied to larger animals, such as scorpions and certain snakes, in which a considerable quantity of venom is formed, and this, injected into man, may produce severe and even fatal symptoms. The venom differs in character in different species of these animals, and the effects in man are diverse.

CHAPTER II.

CLASSIFICATION.

THE metazoa causing diseases or injury to man are so numerous, belong to so many families, and vary so greatly in their habits, that a profound knowledge of zoology is necessary for their satisfactory study. It is proposed in this part to deal at length with the better-known parasitic metazoa only, and with the diseases they cause. Other branches of the subject are dealt with in less detail.

Classification.—In the division of living organisms into kingdoms, orders, families, genera, species, the simplest and most readily demonstrable of the recognized methods of classification is the one adopted. Occasionally an alternative plan is given. It must always be remembered that no classification founded on a single character is sound. For a complete classification, the life-history from the egg to the adult form would no doubt be the best basis. Unfortunately, this is known for but a small proportion of the members of this sub-kingdom.

It is not uncommon to find that some external character in the adult is so frequently associated with certain types of development that it may be used as the basis of classification; but by using this method errors will be made occasionally. The larger the number of external characters used as the basis the fewer will be these errors; but classification so made must always be revised with any advance in our knowledge of development and internal structure.

Living organisms have been divided into two kingdoms, Animal and Vegetable. It is now usual to interpose a third "intermediate" kingdom, the Protista, composed of unicellular organisms, some of which, the Protozoa, in many

characters approach the Animal Kingdom and were formerly included in it, others are allied to the fungi and Vegetable Kingdoms, such as the bacteria or schizomycetes. Members of all classes cause disease.

The multicellular organisms definitely animal in character are known as the Metazoa, and this kingdom constitutes the animal kingdom in the restricted sense. These metazoa forming the animal kingdom are divided into sub-kingdoms, the important ones for our purposes amongst the invertebrata being Vermes, Arthropoda and Mollusca. The Vermes, or worms, are represented by the *Platyhelminths*, such as flukes and tapeworms, and the *Nematohelminths*, as filariæ, round-worms, thread-worms, hook-worms, &c. The Arthropoda, animals with jointed limbs, include the classes *Insecta*, *Arachnida* (spiders, scorpions, and ticks), *Crustacea* (including cyclops, the carrier of the Guinea-worm, and possibly of other parasites). The next sub-kingdom or phylum is the Mollusca, some of which, as snails, oysters, &c., carry parasitic larvæ or micro-organisms.

Of the vertebrate classes, snakes (*Ophidia*) alone are considered. The higher vertebrates, when used as food, occasionally cause disease, and may carry the larval forms of parasites which may develop in man to the adult stage. The carnivora are directly dangerous to man, but these are too well known to require description.

Genera and Species.—The division into genera and species has given rise to much discussion, and the experts have found it necessary with each increase of knowledge of the subject to modify the classifications.

As a general rule, division into genera and species is or should be a convenience, and unless the reasons are very definite, genera should not be formed on single species. On the other hand, a genus composed of a very large number of species is difficult to work with, and subdivision of a genus is necessary, either into several genera or sub-genera.

Species are sometimes divided into sub-species; this

should be avoided where possible, varieties being a preferable term. It must always be remembered that individual variations occur even in the offspring of a single pair, and still more frequently in the progeny of a group of animals belonging to the species. Such individual variation does not constitute specific difference, however great it may be; and the formation of a new species, and still more of a new genus, based on the examination of a single specimen, is to be deprecated.

Nomenclature.—Even more than with Protozoa, difficult questions as regards nomenclature arise. There is at present much confusion. In the past, independent workers have severally described under different names the same parasite. Others, finding the number of parasites described under one generic heading too large, have grouped them into separated genera or sub-genera and done this in different ways. The names originally given for a species or genus often have been ignored, and other, possibly more descriptive, names have been substituted for them. The result of such changes is a wild confusion. Zoologists, realizing this condition, have attempted to rectify it, and it is now decided that the original name is the name to retain: that if a generic name is given that name must be the generic name of the species first described of that series, and that if it is deemed necessary to form other genera, though the generic name is to be altered the specific name remains good.

It is to be hoped that these efforts will be crowned with success, but at present there is still confusion, as according to these rules old names that had become obsolete have had to be revived. A close study of older literature, sometimes a hundred years old, has resulted in displacing familiar names by forgotten ones. It is much to be feared that unless a time limit be made and a definite system of registration adopted further changes will ensue in the nomenclature when the mass of published, but not necessarily printed, literature now hidden in the archives of universities, learned societies and government

reports becomes accessible and is closely studied. Some of the old descriptions are vague, and authorities differ as to what the exact animal was to which the generic or specific name was originally given.

Our present duty is clear: to avoid making use of names, even of provisional names, on any new discovery, without a close study of the names already given and of the literature of the subject. Even as regards the spelling of many of these names there are variations. The names used in this work are in the main those in common use.

Classification of Human Parasites.—If the only worms to be considered were those infesting man, a very simple classification of helminths could be adopted; but, as it is, if human helminthology is not to be in opposition to ordinary zoology, the zoological classification has to be used, though as regards man many genera are not represented and others are only represented by a single species. Closely related though non-parasitic groups may require brief mention.

Helminths are worms parasitic in man or other animals, at some stages of their existence. The diseases or lesions produced are sometimes grouped together under the heading *Helminthiasis.* The helminths found in man belong to many groups and are subject to the zoological methods of classification into Platyhelminths—flukes and tape-worms—and Nematohelminths—round-worms—and each of these divisions is further subdivided. The diseases caused are by some similarly divided according to the group of parasites, or even by others according to species. Some of the terms, such as Filariasis and Ankylostomiasis, are in common use and are, therefore, adopted in this book.

CHAPTER III.

PLATYHELMINTHS.

THE Platyhelminths are worm-like bodies, flattened dorso-ventrally, frequently hermaphrodite, and with an anteriorly placed central nervous system. If there are intestinal tubes they are blind, and as there is no rectum are said to be aproctous. The excretory system consists of ramified tubes. There is no body-cavity. Muscle-fibres are non-striated. There are three main divisions or classes :—

CLASS I, *Turbellaria*, are free-living platyhelminths covered with a ciliated ectoderm. They are not parasitic.

CLASS II, *Trematoda or Flukes*, are parasitic platyhelminths. They are unsegmented and usually flattened or leaf-shaped, but in some species the females are cylindrical. Most species are hermaphrodite. They possess a mouth, opening into an expanded muscular ring or sucker. There is a straight muscular œsophagus which divides into two blind diverticula or cæca. There is no anus. A second sucker, or acetabulum, in addition to the oral sucker, is usually present and serves for fixation.

CLASS III, *Cestoda* (*Tapeworms*), are elongated flattened and segmented platyhelminths. There is no alimentary canal, and the organs for attachment are at the anterior end of the worm. In each mature segment there are complete male and female reproductive organs. These are considered later.

TREMATODA.

The Trematoda parasitic in man are, as far as we know, all digenetic, meaning that the life-cycle from egg

to adult is complex and that asexual multiplication takes place outside the body from the sexually produced egg.

From one egg, containing a single ovum, many flukes are developed. The development of the fertilized ovum commences in the uterine tubes, and in some the embryo is formed before the eggs are passed by their host. In other cases the ovum develops outside the body, so that a mature embryo is formed inside the egg-capsule. The eggs, when fully developed, undergo no further change unless they are in water, when the embryo escapes from the shell as a free-swimming ciliated body—the *miracidium*—which in appearance may be mistaken for an infusorian (fig. 1, *C*).

The larva, if free-swimming, wanders about till it finds a suitable host, usually a mollusc, and then bores its way through the body-wall. If not free-swimming, it is eaten by the new host in its food.

Having entered the tissues of the new or intermediate host, the miracidium loses its cilia and becomes rounded and motionless—the *Sporocyst* (fig. 1, *E*). This usually occurs in the liver of the mollusc. In the interior of the sporocyst young flukes—*Cercariæ*—may be formed. In shape these resemble the adult form with the exception that they are provided with a motile caudal appendage, and in some instances with a boring spine at the anterior extremity. This is a rare but comparatively simple method.

Often a still more complicated process takes place; the bodies formed in the sporocyst do not in the least resemble the adult form of flukes, and do not directly develop into such adult forms.

In this method of multiplication the contents of the sporocyst are converted into tubular worm-like bodies (fig. 1, *F, G*), with a mouth and primitive intestine—*Rediæ*—and it is in the body of such rediæ that the cercariæ, or immature flukes, are formed. As several rediæ are formed and each of these forms several cercariæ a double asexual multiplication takes place (fig. 1, *H*). These cercariæ

FIG. 1.—Life-cycle of Fasciola. *A*, adult, sexually mature. *B*, ovum; *C*, *D*, miracidium; *E*, sporocyst; *F*, sporocyst with rediæ formed; *G*, young redia; *H*, redia with cercariæ formed; *I*, free cercaria; *K*, encysted cercaria; *L*, young trematode not sexually mature.

escape from the redia, and usually from their intermediate host (or else migrate to another host), and after a brief free life in water or encysted on blades of grass, enter the body of their definitive host, and become sexually mature, losing their caudal motile appendage or tail early (fig. 1, *L*).

It will be seen from this that from the one fertilized egg either several cercariæ are formed, each capable of becoming an adult trematode, or that the process of asexual multiplication may be repeated, and from one fertilized egg several rediæ may be produced, and from each redia many cercariæ. Each cercaria may become an adult sexually mature trematode (fig. 1).

For this process of development an intermediate host is necessary. Such hosts are molluscs in the known instances, with the exception that the development of the Schistosomidæ beyond the Miracidium is unknown.

The life-cycle of the digenetic trematodes consists, therefore, of alternations of generations.

The adult is the sexual generation producing eggs and fertilizing them. The eggs parthenogenetically produce other generations. The process is known as Heterogenesis.

The families into which the digenetic Trematodes are divided are best considered after a brief review of the anatomy of the adult forms of these flukes, as variations in the structure of the different parts are the basis of the scientific classification.

Structures in Adult.—The alimentary canal is composed of a terminal mouth surrounded by a muscular ring which forms the anterior or oral sucker. From the mouth a short, straight, muscular œsophagus passes backwards, and in this œsophagus there may be lateral pouches.

The œsophagus terminates in a bifurcation to form the intestine. This is thin-walled, and each half is continued backwards, terminating blindly. The intestine varies. There may be numerous pouches, or diverticula,

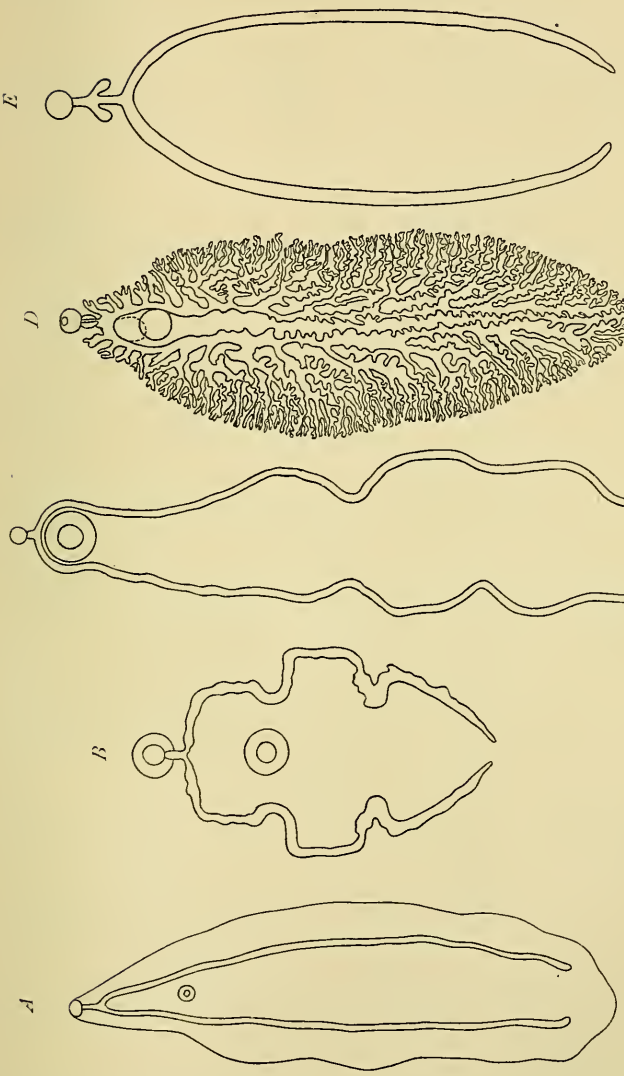


FIG. 2.—Types of alimentary canal. *A*, simple, as in Clonorchis, &c.; *B* and *C*, sinuous, *e.g.*, Fasciolopsis; *D*, branched, *e.g.*, Fasciola; *E*, with œsophageal pouches, *e.g.*, Cladorchis.

which in turn may be branched, or there may be no branching and the intestine is then said to be simple. There is no anus (fig. 2).

A second muscular ring, a fixative sucker, sometimes known as the acetabulum, is present in most of the families. It has no connection with the intestine. The genital opening may be close to it, but this opening is never in the acetabulum.

The excretory system consists of a series of tubes joining to form an excretory duct opening at the posterior extremity.

The nervous system consists of a bilobed ganglionic mass above the œsophagus, from which are derived two ventral trunks and two smaller dorsal trunks. All these trunks are connected by transverse branches which anastomose. Eye-spots are present in some species.

Reproductive Organs.—The *Fasciolidæ* and *Paramphistomidæ*, the largest groups of the trematodes, are hermaphrodite, male and female organs being present in the same individual. The *Schistosomidæ* form a separate group, as the male and female organs are in different individuals, and there are several testes.

The testicles are double in the other trematodes, and there is a single ovary. Both testicles and the ovary may be branched, lobulated, or in a single mass. These differences are of value in the subdivision of the group into genera (figs. 3 and 4, *B* and *C*).

Male Organs.—The testicles, whether branched or not, are large. They may be situated posteriorly or anteriorly. From each testicle proceeds a tube—the vas deferens—which passes forward and unites with its fellow to form a sac—the cirrhus pouch—in which is enclosed a protrusile organ—the penis. The opening is close to the opening of the female organ in the hermaphroditic species (fig. 3).

Female Organs.—These are more complicated. There is a single ovary, round and compact, or branched. From this leads an ovarian tube, and into this tube opens

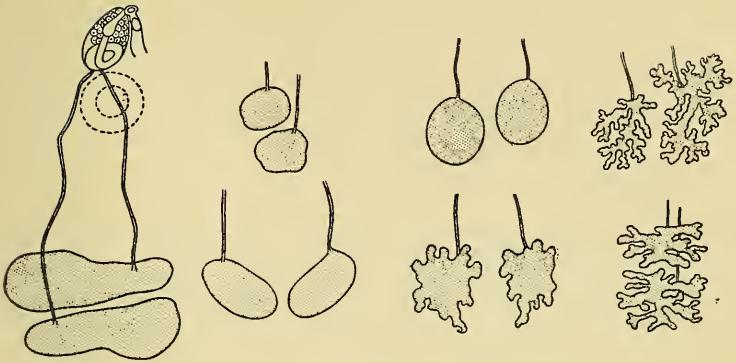


FIG. 3.—Types of testes in the Fasciolidæ.

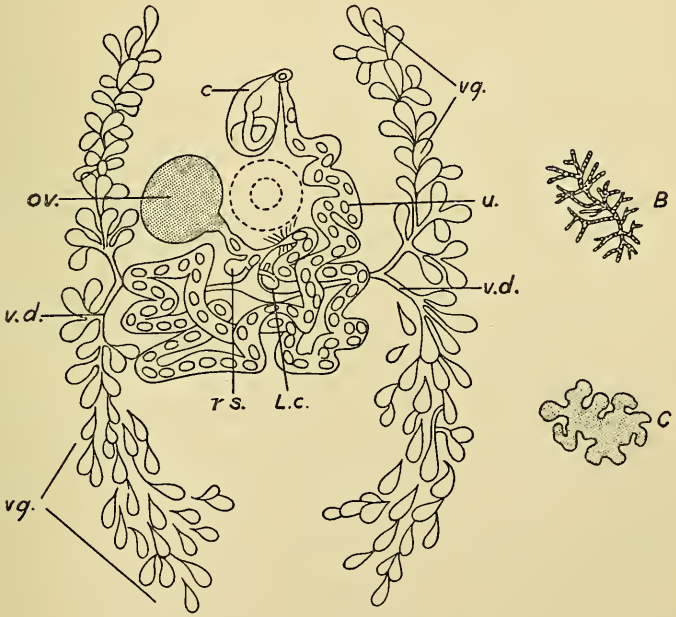


FIG. 4.—Female genital organs in Fasciolidæ. *ov.*, ovary; *v.d.*, vitelline ducts; *v.g.*, vitelline glands; *r.s.*, receptaculum seminis; *L.c.*, Laurer's canal; *u.*, uterus; *c.*, cirrhus pouch. *B* and *C*., other types of ovaries—branched.

obliquely the opening of a sac—the *spermatheca*, or *receptaculum seminis*—in which the spermatozoa are stored up. A second tube leads into the ovarian tube from the dorsal aspect of the worm, and is known as the canal of Laurer. The function of this tube is not clearly understood.

The ovarian tube, after the junction of these tubes, is dilated, and surrounded by a mass of glands, the shell-glands. Into this dilated portion of the ovarian tube two ducts open, those of the much branched yolk-glands—*vitellaria*—which are situated near the lateral edges of the worm. In the dilated portion of the ovarian tube—the *oötype*—the ova are fertilized by the spermatozoa, which are discharged from the spermatheca. They also receive the abundant yolk-masses and are provided with a shell or envelope.

From the oötype the eggs pass through a convoluted tube—the *uterus*. This opens externally at the genital pore, which is situated on the ventral aspect (fig. 4).

Though most of the trematodes are hermaphrodite, copulation of two individuals is the rule. This may take place either by the injection of the spermatozoa of one individual into the uterus of another, or, according to some, through the canal of Laurer. Auto-fertilization may take place, as the openings of the male and female organs, though separate, are close together.

The digenetic trematodes are divided into two great divisions: (1) Those which are hermaphrodite, male and female organs in the same individual—the *Fasciolidæ*, *Paramphistomidæ*, &c.; and (2) those in which the male and female organs are in separate individuals—*Schistosomidæ*.

CHAPTER IV.

TREMATODES PARASITIC IN MAN.

(1) *Monostomidæ*, in which only the anterior or oral sucker is present. There is no second sucker or acetabulum (fig. 5, *A*). The genital pore is ventral and about the middle. They are usually found in the alimentary canal of certain vertebrates.

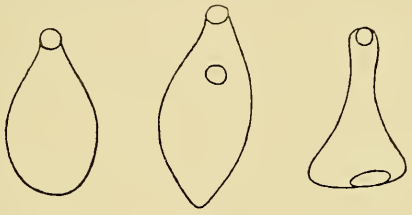


FIG. 5.—Diagram of arrangement of suckers. *A*, Monostoma; *B*, Distoma or Fasciolidæ; *C*, Paramphistoma.

In man the *Monostoma lentis*, of which immature forms have once been found in the lens of the eye, is the only known representative, and it is doubtful if this is not the young form of some other parasite.

The other families have both the oral sucker and a second sucker or acetabulum. There are three families represented in man :—

(2) *Fasciolidæ*, in which the second sucker is ventral, not further removed from the oral sucker than the middle of the body (fig. 5, *B*).

(3) *Paramphistomidæ*, in which the second sucker is at the posterior end of the body (fig. 5, *C*).

(4) *Schistosomidæ*.—The male and female forms are separate individuals, *i.e.*, they are not hermaphrodite. The second sucker is ventral and near the oral sucker.

Fasciolidæ.

The Fasciolidæ are common flukes in many of the domesticated animals, and several genera are represented in man. Some of the species found are probably only accidental parasites in man, as they are much more common in other animals, *e.g.*, *Fasciola hepatica ;* others, as the *Clonorchis sinensis,* are only known in man.

The known human Fasciolidæ, including accidental parasites, can be readily distinguished by their external characters as a rule, as few species of each genus occur in man. The external appearances are as follows :—

In the *Fasciola,* the head is a definite conical projection from the rest of the body, and the ventral sucker is not much larger than the oral. The branched intestine, if it contains food, can usually be seen. *Fasciola hepatica,* an accidental parasite of man, is the representative of this group.

Fasciolopsis is represented in man by at least two species. In neither of these is there a definite differentiation between the head and the rest of the worm. The very large and deep ventral sucker is the striking characteristic. In addition, the large cirrhus pouch is a conspicuous object, and in many specimens the sinuous but not pouched alimentary canal can be seen. The single species of Fascioletta is so small that it is not likely to be confused with Fasciolopsis.

The narrower and smaller flukes belonging to the Fasciolidæ have no differentiation between the head and the rest of the body. They can be divided into two groups : (1) those with the ventral sucker near the anterior sucker, and (2) those where the ventral sucker is near the middle of the ventral surface.

(1) Of those with the ventral sucker anterior, one parasite accidental in man, the *Dicrocœlium,* can be readily distinguished, as the uterus, distended with eggs, is clearly visible in the posterior half of the body. The testicles, which are difficult to see with the naked eye in unstained

or uncleared specimens, occupy the anterior half. In the others the testicles occupy the posterior half, and the uterine coils are therefore only to be seen in the anterior half, in these the ovary is anterior. Two genera, *Opisthorchis* and *Clonorchis* are represented in man, but are not readily distinguished from each other in uncleared and unstained specimens.

(2) Two species are known in man with the ventral sucker in the middle line, and these belong to different genera.

Heterophyes heterophyes is the smallest of the human flukes, and the ventral sucker is much larger than the oral. Paragonimus, represented by *Paragonimus westermani*, is a much larger and more fleshy fluke. The ventral sucker is about the same size as the oral sucker.

This grouping on external characters only is not satisfactory when the parasites of other animals have also to be considered, and therefore it is much sounder to group according to structural differences, which in specimens rendered transparent by glycerine or creasote, with or without staining, can be readily made out.

Fasciola.

Fasciola.—Ovary and testicles much branched. The testes are posterior. Numerous branching diverticula of the intestine.

In *Fasciola hepatica*, which has rarely been found in man, but is common in sheep and cattle, the branched intestinal diverticula are all on the lateral margins of the worm ; simple diverticula only on the internal aspect. It inhabits the bile-ducts and gives rise to dilatation of these ducts, with considerable thickening. It may cause extensive destruction of the liver and the formation of abscesses. It is a pathological curiosity in man (fig. 6).

Fasciolopsis.

Fasciolopsis.—Ovary and testes branched. Testes posterior. Cirrhus pouch very large. Intestine not branched

but usually sinuous. The acetabulum is very large and deep. Three species have been described in the human intestine.

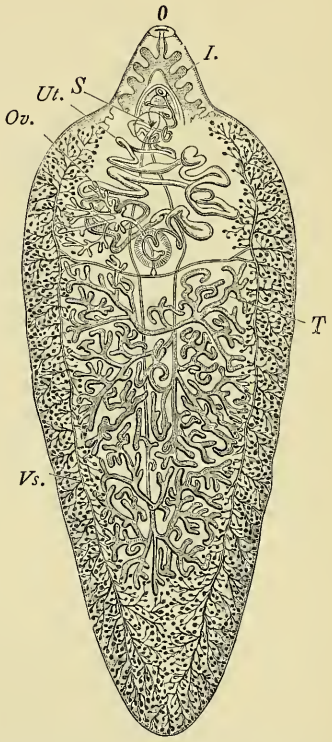


FIG. 6.—*Fasciola hepatica*, L. *I.*, intestine; *Vs.*, vitelline sacs; *Ov.*, ovary; *O*, oral aperture; *Ut.*, uterus; *S*, ventral sucker; *T*, testes. (After Claus.)

Fasciolopsis rathouisi.—In this species the testes are side by side, and the worm is broad in proportion to its length, 16 by 25 mm. It is a rare parasite; it occurs in the intestines, and has been found only in China. A redescription of the types shows that the testicles are really behind each other and not arranged side by side as in the original description from which fig. 7 is taken. Possibly it is the same as *F. buski.*

Fasciolopsis buski is the largest of the human trematodes. It measures up to 70 mm. in length, but is usually 24 to 25 mm. by 5·5 to 12 mm. It is also found in pigs.

The large size of the acetabulum renders the genus *Fasciolopsis* easy to identify. The uterus is convoluted and anterior. The intestinal tubes are also sinuous, but

FIG. 7.—*Fasciolopsis rathouisi* (Poir.). The mouth at the top, and under it the genital pore and ventral sucker, behind which again is the uterus. The vitelline sacs are at the sides, and posteriorly in the central field the ramified testes, the ovary is in front of the right one. (After Claus.) A re-examination of the types shows that the testes are behind each other, not as in the original description from which this figure is taken.

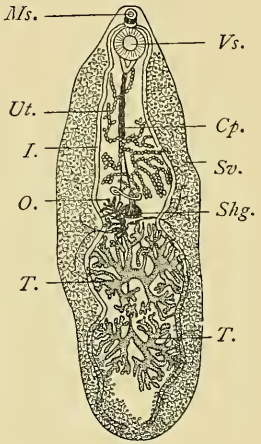


FIG. 8. — *Fasciolopsis buski* (Lank.). *Vs.*, ventral sucker; *Cp.*, cirrhus pouch; *I.*, intestinal fork; *Sv.*, vitelline sac; *T.*, testes; *O.*, ovarium; *Ms.*, mouth sucker; *Shg.*, shell-gland; *Ut.*, uterus. (After Odhner.)

not branched. The ovary is branched. The testicles also are much branched and placed one behind the other. The vitellaria—yolk-glands—occupy the edges of the worm throughout nearly the whole of the body-length.

The intermediate host is not known. The geographical distribution is probably China and India only, as the cases recorded elsewhere, in British Guiana, for instance,

were in people from India. It is a common parasite of pigs and is commoner in man than the recorded cases indicate. This fluke has been found in Assam more frequently than in other parts of India. It lives in the intestine, and up to thirty specimens have been found in one individual.

In some of the cases there has been marked anæmia, but as the patients also had ankylostomes it cannot be proved to have caused this anæmia. Persons harbouring this parasite often have dysenteric symptoms. The worms are expelled after the administration of thymol.

A third species, *F. fulleborni*, has been described. In this also the testicles are behind each other as in *F. buski*, (fig. 8).

There is a good deal of variation in the different specimens described as *F. buski*, and whether the variations are sufficient to amount to specific differences, and whether *F. fulleborni* is a separate species, or merely represents one of these variations, is not yet certain. More specimens are required.

Paragonimus.

Paragonimus.—The ovary and testes are branched, the former slightly. The testes are posterior and side by side at nearly the same level. The intestine is sinuous but not branched. The ventral sucker is slightly anterior to the middle line and about the same size as the oral sucker. The opening of the genital organs is posterior and to one side of this sucker. Yolk-glands are very numerous and extend anteriorly almost to the œsophagus (fig. 9).

Paragonimus westermani is found in tiger cats in the East, and in man in China, the Philippines, and Japan.

It is a thick, fleshy fluke, 8 to 10 mm. in length and 4 to 6 mm. in breadth. It is usually found in the lungs, and the eggs are discharged with the sputum. In persons infected with this parasite attacks of hæmoptysis are frequent and may be profuse. There is a considerable

amount of bronchitis, so that thick, tenacious mucus, sometimes streaked or tinged with blood, is expectorated. The symptoms, particularly when there is any acute pulmonary exacerbation, may easily be mistaken for pulmonary tuberculosis. The diagnosis is readily made by examining the sputum for eggs. Although the pulmonary symptoms are the ones that attract attention, so much so, that the disease is often called *endemic hæmo-*

FIG. 9.—*Paragonimus westermani.* (After Looss.)

ptysis, the infection is not always limited to the lungs. Parasites have been found in various parts of the body, including the kidneys, intestine, brain, and occasionally cause the formation of large abscesses.

Treatment.—The treatment of the endemic hæmoptysis is symptomatic, and in the majority of cases the prognosis is good and little serious trouble results. When the hæmoptysis is profuse absolute rest is necessary. The associated bronchitis should be treated in the ordinary manner.

Prophylaxis.—Though probably carried by a mollusc the particular species is unknown. It is not certain how man becomes infected. It is not probable that the cercariæ

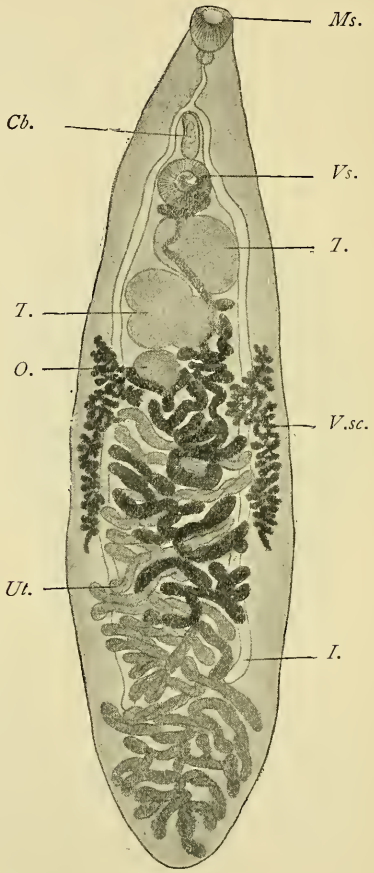


FIG. 10.—*Dicrocœlium lanceatum*, Stil. and Hass. 15/1. *V.s.*, ventral sucker; *Cb.*, cirrhus pouch; *I.*, intestinal bifurcations; *V.sc.*, vitelline sacs; *T.*, testicles; *O.*, ovarium; *Ms.*, oral sucker; *Ut.*, uterus.

are inhaled, but like the cercariæ of other flukes, are probably taken into the mouth with uncooked vegetables or in drinking water. How they find their way to the lungs

is unknown. Destruction of sputum of the patients is hardly practicable.

An accurate knowledge of the intermediate hosts, of the usual hosts and their habits would perhaps render it possible to prevent or diminish the frequency with which these infections take place.

In the genera next to be considered, the ovary is round or lobulated, not branched. The intestines are nearly straight, and there are no diverticula. The cirrhus pouch is inconspicuous. In *Dicrocœlium* the testicles are lobulated and anterior. *D. lanceatum* is an occasional accidental parasite of man (fig. 10). In the others the testes are posterior, either lobulated and placed one behind the other (*Opisthorchis*) (figs. 11 and 13), side by side (*Metorchis*) (fig. 12), or much branched (*Clonorchis*) (fig. 14).

In these groups the extent to which the lateral margins are occupied by the yolk-glands is of value as indicating a specific difference. The presence or absence of spines on the cuticle is of importance. Size, within limits, varies so much that even with the sexually mature worms it is of little value. The size of the eggs is of more value.

Opisthorchis noverca and *O. conjunctum* have been found in man, but are rare parasites in him; the dog is the true host (figs. 11 and 13).

Opisthorchis noverca (*Distomum conjunctum*) is found in man in India. The spines on the cuticle, and the distribution of the yolk-glands, which are in the middle of the body (fig. 13), distinguish it from *O. conjunctum* (fig. 11), also a rare accidental parasite of man.

Clonorchis.

Clonorchis differs in that the testes are much branched. They are arranged one behind the other. One species of Clonorchis is a very common parasite in Chinese—*Clonorchis sinensis*.

Clonorchis sinensis is a narrow worm with a bluntly rounded extremity, and tapering slowly to a slightly sharper tail. It ordinarily measures 10 to 14 mm. by

2·4 to 3·8 mm. The ovary is lobulated, and the testicles are much branched. It inhabits the gall-bladder and bile-ducts of man. It is a common parasite in the Chinese, and may be found in about 1 per cent. of autopsies, enormous numbers being often present.

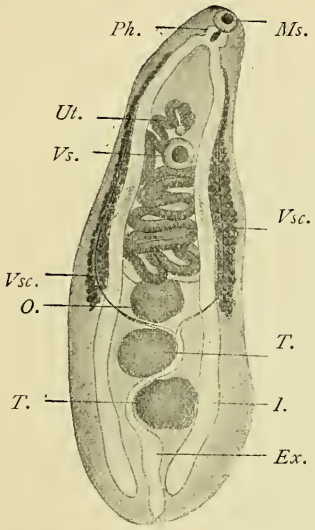


FIG. 11.—*Opisthorchis conjunctum*, Cobb (*nec* Lewis and Cunn, *nec* McConnell), from *Canis fulvus*. *Vs.*, ventral sucker, ; *I.*, intestine ; *Vsc.*, vitelline sacs ; *Ex.*, excretory bladder ; *T.*, testes ; *O.*, ovary ; *Ms.*, oral sucker ; *Ph.*, pharynx ; *Ut.*, uterus. (After Cobbold.) In *O. felineus*, found in the cat with which this was at one time confused, the testes are lobular.

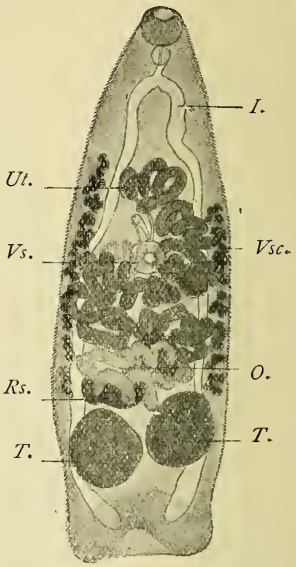


FIG. 12.—*Metorchis truncatus*, Rud., from the biliary ducts of the domestic cat. 25/1. *Vs.*, ventral sucker ; *I.*, intestinal fork ; *Vsc.*, vitelline sacs ; *T.*, testes ; *O.*, ovary ; *Rs.*, receptaculum seminis ; *Ut.*, uterus.

As an indigenous parasite its geographical distribution is limited to the Far East. The Chinese in any part of the world may be found to harbour the parasite, but it does not appear to spread when introduced into other countries. The intermediate host has been shown to be a fish by Kobayashi. The fish he proved to be

carriers were *Pseudorasbora parva* and *Leucoyobia*, and others to a smaller extent (Günthere). The encysted distoma are found in the flesh of these fish, and when this is swallowed the flukes become mature in kittens in three weeks or more.

FIG. 13.—*Opisthorchis noverca*. 6/1. (After Leuckart.)

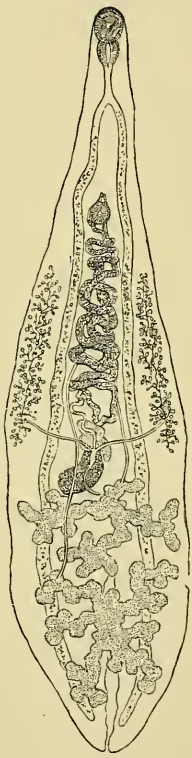


FIG. 14.—*Clonorchis sinensis*, Cobb, seen from the ventral surface; extended. (After Leuckart.)

Many persons who harbour this parasite appear to be in good health, and when death occurs it is usually from some cause unconnected with the parasite. Even in these cases there is a considerable amount of biliary cirrhosis caused by this parasite, and the bile-ducts in

which they occur are dilated and the walls much thickened. The gross organic lesions so produced give rise to definite disease in few cases.

In some cases in these dilated, thickened ducts biliary calculi form, so that sometimes numerous small calculi are found in many of the dilated ducts, and following this condition an acute pyogenic infection of the bile-ducts occurs. Rarely a large solitary abscess forms and this may attain a considerable size and burst into the pericardium or elsewhere.

Clonorchis sinensis has also been found in the pancreas.

There is no possibility of removing these worms, and the treatment, therefore, must be symptomatic.

Prophylaxis.—In spite of the rarity of dangerous symptoms, it is advisable to prevent as far as possible infection with these flukes.

The limited range of distribution of the different species of flukes is best explained on the assumption that the distribution of suitable intermediate hosts is also confined to special localities.

The habit in the East of using human fæces for manure, and the fact that rice cultivation is specially adapted for the growth of molluscs and certain fish, probably explains the frequency of trematode infections in China and Japan.

The eggs of trematodes are resistant and are not destroyed by passage through the intestines of larvæ of flies. Nor are they destroyed rapidly when fæces are desiccated or allowed to putrefy. Even if the excrement is stored for a long time living eggs will still remain, and when the excrement is mixed with water and used as manure, particularly in padi fields, the miracidia will escape and infect a suitable host. The complete change in the habits of the people and the economic loss that would result from more complete destruction of the fæces render it improbable that infection will be entirely prevented.

ECHINOSTOMA.

Echinostoma (*Fascioletta* Garrison). One species known, found in Luzon, Philippines. The presence of a ring or crown of spines round the anterior extremity of the body removes this worm to the genus *Echinostoma*. Small flukes. Ovary anterior to testes. Both unbranched

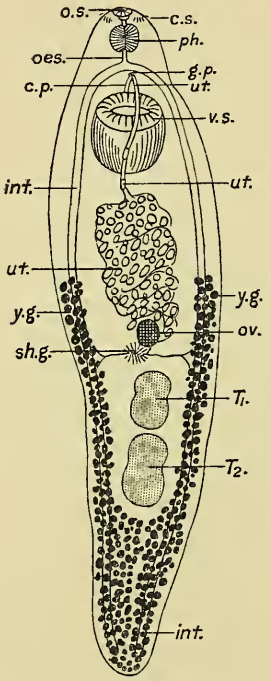


FIG. 15.—*Echinostoma ilocanum* (Garrison), 1908. *o.s.*, Oral sucker; *v.s.*, ventral sucker; *œs.*, œsophagus; *g.p.*, genital pore; *ut.*, uterus filled with eggs; *c.s.*, collar of spines; *c.p.*, cirrus pouch; *int.*, lateral gut branch; *y.g.*, yolk glands; *ov.*, ovary; *sh.g.*, shell gland; *ph.*, pharynx.

testes bilobed. Ventral sucker very large, nearly three times the size of the oral sucker; both suckers near to each other. Intestine has no diverticula. No cephalic cone. Greatest width and thickness are about the

junction of anterior and middle third and tapers from that point posteriorly.

Echinostoma ilocana (fig. 15).—Eggs have been found in the motions of five patients from Luzon district. 4 to 6 mm. in length; greatest diameter 0·75 to 1·35 mm., and thickness 0·5 to 1·0 mm.

Oral sucker broader than long, 150 μ by 100 μ. Dorsal lip most prominent. Ventral sucker 500 μ in diameter.

Œsophagus short; cæca extend nearly to the posterior extremity. No branches. Ovary globular and about the middle of the body. Testes indistinctly bilobed. Genital pore anterior to the acetabulum. Yolk-glands abundant and extend from the level of the acetabulum to the extreme posterior end of the worm.

The worms were expelled after treatment by thymol; they are therefore intestinal, and no symptoms are known to be caused by them. Eggs operculated, yellowish in colour, 100 μ by 6 to 7 μ.

Echinostoma malayanna found at a *post-mortem* in the Malay States. 8 to 12 mm. long by 3 to 3·3 mm. in breadth. Testes lobulated, the anterior the smaller. The spinous ring composed of 43 spines.

Heterophyes.

Heterophyes.—The ovary and testes are rounded bodies. The testes are posterior to the ovary and nearly at the same level. The ventral sucker is much larger than the oral, it is nearly in the middle of the ventral surface and the openings of the genital organs are below and to one side of it.

The yolk-glands are not numerous.

Heterophyes heterophyes is found in natives of Egypt and has been found in Chinese and Japanese in London. It occurs in the intestine. It is a very small fluke, only 1 mm. long by 0·5 mm. broad, and it is so easily overlooked that it is probably a more common worm than it is usually supposed to be (fig. 16). It may be associated with dysenteric diarrhœa.

Saline aperients cause the expulsion of some worms, but thymol in addition is required for the expulsion of the majority.

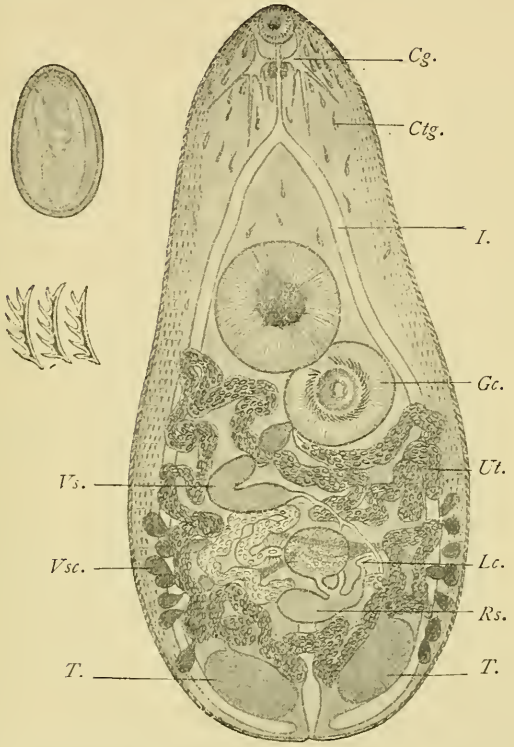


FIG. 16. — *Heterophyes heterophyes* (v. Sieb.). 53/1. *Cg.*, cerebral ganglion ; *I.*, intestinal branches ; *Ctg.*, cuticular glands ; *Vsc.*, vitelline sacs. ; *G.c.*, genital cup ; *T.*, testes—the excretory bladder between them ; *Lc*, Laurer's canal ; *Rs.*, receptaculum seminis, with the ovarium in front of it ; *Ut.*, uterus ; *Vs.*, vesicula seminalis. On the left side above, an egg, 700/1, is depicted, and below it three chitinous rodlets from the genital cup, 700/1. (After Looss.)

Yokogawa yokogawa, a small fluke 1·1 to 1·14 long and ·42 to ·7 mm. in breadth, widely distributed amongst the inhabitants of Japan, Korea, and Formosa. It is also found in dogs. The parasite resembles *Heterophyes*, but there is no ventral sucker, and the disc round the genital

pore does not carry the ring of "antlers" peculiar to *Heterophyes*. The ovary and testes are not lobed. The yolk glands are few and grouped into fairly large masses.

Paramphistomidæ.

In these the oral sucker is at one extremity and the second sucker is more or less at the opposite extremity.

The classification of this family has varied. According to Stiles, these should be divided into two groups—those with œsophageal pouches and those without. The pouches are not prominent features, or easy to see in uncleared specimens. The classification is therefore to that extent inconvenient.

According to this grouping, both of the human species of *Paramphistomidæ* belong to the *Cladorchinæ*, as there are lateral pouches on the œsophagus in both.

The older division is based on external characters easy to distinguish, and in man each of the two known species belongs to a different division.

(1) *Amphistomum or Paramphistomum*,[1] in which the worm is more or less conical, the anterior edge being narrow and the posterior broad, and *Gastrodiscus* in which the posterior extremity is expanded into a broad, flattened plate, the anterior part appearing as a conical projection springing from the dorsal surface of this plate. One of the commonest of all flukes, the *Amphistomum conicum*, is found in enormous numbers in the stomachs of cattle in most parts of the world. It does not appear to cause any symptoms or disease in them.

No true Amphistomum is known to occur in man. The fluke originally termed *Amphistomum watsoni* is described as a *Cladorchis*, as there are pouches on each side of the œsophagus, and the genus is known as Watsonius.

Watsonius (*Cladorchis*) *watsoni*.—This parasite occurs

[1] Paramphistomum, though the worse Greek, is the correct name zoologically.

in West Africa, in Northern Nigeria, and is said to be a common parasite in Bornu and the neighbourhood of Lake Chad. According to Blair, considerable anæmia and debility is caused by this parasite, and not infre-

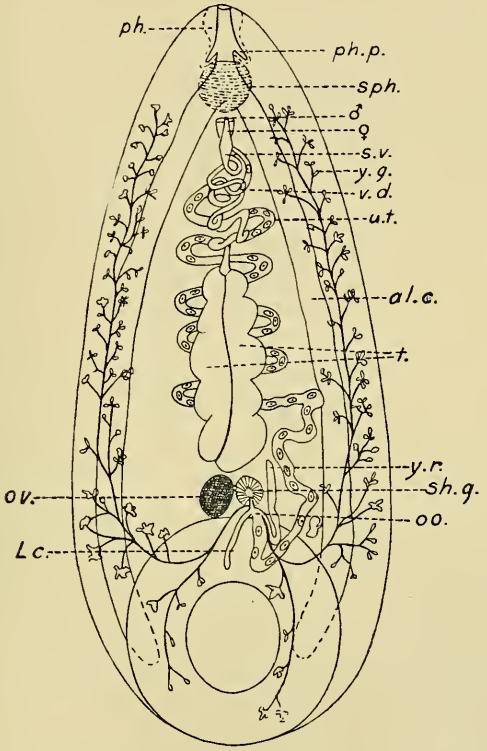


FIG. 17.—*Watsonius watsoni.* (After Shipley.) *ph.*, pharynx; *ph.p.*, pharyngeal pouch; *sph.*, sphincter; *s.v.*, seminal vesicle; *y.g.*, yolk glands; *v.d.*, vas deferens; *ut.*, uterus; *al.c.*, alimentary canal; *t.*, testes; *y.r.*, yolk reservoir; *sh.g.*, shell glands; *oo.*, oötype; *ov.*, ovary; *L.c.*, Laurer's canal.

quently death results. The testes are lobulated, elongated, and are pressed close against each other. The ovary is round and is posterior to the testes. The anterior or oral sucker is very small, hardly a definite sucker (fig. 17).

Nothing is known of the life-history or intermediate host of this parasite.

Gastrodiscus hominis (*Amphistomum hominis*) was first described by Lewis and McConnell in 1876. It is a small gastrodiscus, and the flat plate forming the posterior extremity is concave; behind the centre of the concavity is the acetabulum. The under-surface of this disc is smooth and not marked by any of the papillæ or projections so common in many of the species belonging to this genus, *e.g.*, *Gastrodiscus sonsino*, common in horses throughout Africa. The opening of the genital pore is at the base of the conical part of the worm, not on the disc (fig. 18).

FIG. 18.—*Gastrodiscus hominis*. Slightly magnified. (After Leuckhart.)

Gastrodiscus hominis is a common parasite in Assam, and has been found in other parts of India. Outside India it has only been found in natives of India, and is therefore in such countries an imported parasite. It does not seem to spread under these conditions. This parasite is found in the alimentary canal, and is expelled when thymol is administered.

Anæmia has been attributed to this parasite, but, as in the case of Fasciolopsis and other flukes, the parasites were associated with Ankylostoma, and therefore the anæmia may have been due to those worms. Dysenteric symptoms have been present in most cases.

DIAGNOSIS OF TREMATODE INFECTION.

For the diagnosis of the presence of these worms it is not necessary to find the adult, as the eggs are discharged from the body in the fæces, when the parasites inhabit

the liver or alimentary canal, and in the sputum, when the parasites are living in the lungs or bronchi; and therefore microscopic examination of fæces or sputum will show the presence of these eggs. These serve for the diagnosis of the presence of the adult.

Ova.—The eggs of the Fasciolidæ and Paramphistomidæ have a definite shell, usually yellow in colour, and with a lid (operculum) at one end. In shape they are not quite oval, as one end is narrower than the other. The contents of this shell are the ovum, which forms only a small part, and yolk-masses, a series of more or less rounded refractile globules. The eggs of the human species have been fully described; they differ in shape and colour to some extent but usually are best distinguished by their measurements.

MEASUREMENTS OF TREMATODE OVA.

Fasciola hepatica	0·13 by 0·08 mm.
Fasciolopsis buski	0·125 ,, 0·77 ,,
Dicrocœlium lanceatum ...	0·04 ,, 0·03 ,,
Clonorchis sinensis	0·27 ,, 0·016 ,,
Echinostoma ilocana	0·1 ,, 0·06 ,,
Heterophyes heterophyes ...	0·03 ,, 0·017 ,,
Paragonimus westermani ...	0·08 to 0·1 ,, by 0·052 to 0·075 mm.
Gastrodiscus hominis	0·15 by 0·07 ,,
Watsonius watsoni	0·12 ,, 0·075 ,,
Schistosomum hæmatobium ...	0·08 ,, 0·03 ,,
Schistosomum japonicum ...	0·06 to 0·09 ,, by 0·03 to 0·05 mm.

Treatment of Intestinal Flukes in General.—The intestinal flukes are easily got rid of by treatment with thymol used as for ankylostomes. Those in the bile-ducts cannot be dislodged.

CHAPTER V.

SCHISTOSOMIDÆ.

THE *Schistosomidæ* as causes of disease are of great importance. Several species are known in the lower animals, such as *Schistosomum indicum* in horses in India, *S. crassum* in cattle in Egypt and Malaya. In these the spine on the ovum is terminal. Two definite species are known to occur in man, *S. hæmatobium* and *S. japonicum*. *S. hæmatobium* (*Bilharzia hæmatobia*) may be taken as the type of the bisexual trematodes. The male is the larger and is a broad, flat worm bent longitudinally on itself, so that the two lateral edges are in contact or even overlap. A tube is thus formed, and in it the female is found. This tube is known as the gynæcophoric canal. There are two prominent suckers. The anterior, oral, sucker is terminal. The œsophagus is short and straight, and the bifid intestine anastomoses with its fellow frequently. The contents of the intestine are usually black. The testicles are rounded masses and variable in number, apparently even in the same species. The vasa deferentia unite and open near the posterior sucker, and the female opening is situated opposite it, in the usual position in which the males and females are found. The outer dorsal surface of the male is studded with projecting bosses, so that the surface is much roughened, and probably this aids in the movements of the worm in the blood-vessels and in the retaining of a selected position when it is attained. The male is 15 to 18 mm. in length, and when flattened out 3 to 5 mm. in breadth. The female is longer, so that at each end it projects from the gynæcophoric canal. It is 20 mm. in length, and is a thin, cylindrical worm only 0·25 mm. in breadth. The suckers

are prominent, and the intestine is similar to that of the male. The worms living in contact, the female enfolded in the gynæcophoric canal of the male, are found in the blood-vessels (veins) in the portal circulation.

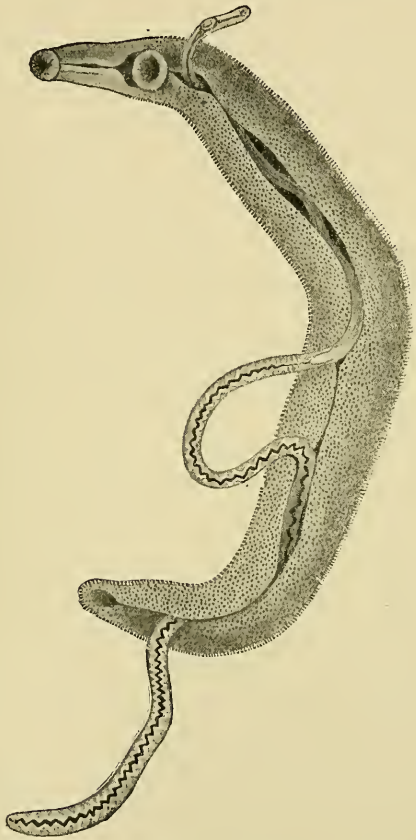


FIG. 19.—*Schistosomum hæmatobium*, Bilh. 12/1. Male contains the female in the canalis gynæcophorus. (After Looss.)

The eggs are discharged from the uterus of the female, and differ from those of the other trematodes in that there is no operculum. They are armed with a single sharp spine, as in most of the *Schistosomidæ*. They pass out

of the vessels into the connective tissue, and are ultimately extruded through the mucous membrane of the genito-urinary system, biliary ducts, intestine, or the rectum.

The common series of clinical manifestations or dieases due to the *S. hæmatobium* are the effects of the passage of these eggs through the tissues of the host.

The adult worm causes no disease, though the walls of the vessels containing the worms appear to be thickened, but the irritating effects of the eggs are considerable. These effects are usually limited to the submucosa, and consist of inflammatory growth, of the formation of granulation tissue; and sometimes also of hypertrophy of the mucosa. This may be sufficiently abundant to form visible masses or papillomata. These are common in the rectum and at the orifice of the anus. Similar papillomata are found in the ureters and pelvis of the kidneys. Rarely they are found under the skin round the orifice of the anus. The adult worms are often found in the liver. The ova in the liver are usually those with the lateral spine. Possibly the hepatic cirrhosis so common in the African native may in some cases be due to this worm.

Whether visible papillomata are found or not in the alimentary canal, there is thickening of the submucosa, and in this the eggs are found in enormous numbers. The mucosa, as the eggs pass into and through it, becomes definitely inflamed, and thick mucus is discharged from the surface, usually with some blood. The eggs are discharged at the same time.

When this occurs in the rectum, the prominent symptoms of dysentery may be produced—tenesmus, with passage of blood and mucus, and severe pain. In many cases the symptoms are not dysenteric, but partake more of the nature of a chronic diarrhœa, with wasting and marked anæmia.

The most common and troublesome results met with are those when the eggs are passed through the mucous membrane of the bladder and ureters. In the inflamed and thickened membranes this passage results in (1)

hæmorrhage and (2) cystitis. The two conditions are associated in varying degrees. The hæmorrhage may be profuse, and the resulting condition is the so-called *endemic hæmaturia*. Hæmorrhage may be constant but varying in amount, but more commonly is only met with whilst the patient is at work, and sometimes occurs only after violent exertion. It may be intermittent and not occur for prolonged periods.

The cystitis is also variable and sometimes intermittent, but is not as a rule of the same severity as the cystitis that results from a bacterial invasion, nor is it associated with decomposition of the urine. This condition may be superadded. Usually there is a discharge of mucus, with or without blood. In the milder cases this is not in large amount, and the urine passed naturally may be quite clear and free from mucus. If, after the urine has been so passed the patient strains forcibly, in the few drops that will now exude mucus may be found abundantly. In this mucus the eggs with the terminal spine will be found readily.

Complications.—Sometimes a large vessel may be opened and severe hæmorrhage occur, so that the bladder may be filled with blood, which then clots. This blood-clot may be broken up with a catheter, and can then be washed out of the bladder. In rare cases perineal section may be required. Cirrhosis of the kidneys may be a late result and attended by high blood-pressure, cardiac hypertrophy and all the symptoms of interstitial nephritis.

Formation of Calculus.—The frequency of bilharzia in Egypt is usually considered to afford an explanation of the frequency of vesical calculus in that country. The eggs may be found in such calculi. On the other hand, bilharzia disease is very common throughout Tropical Central Africa and in South Africa, where vesical calculus is almost unknown and must be rare. *S. hæmatobium*, therefore, cannot be considered as the only cause of the prevalence of vesical calculi in Egypt. Fistula, which in Egypt is said to be a frequent result, does not occur elsewhere.

Severe attacks of pain referred to the pubic region are said by Turner to sometimes occur without any increase in vesical symptoms. In some of his cases there was hydronephrosis.

The eggs are shown by Turner to be frequently present in the lungs, and he believes that this may account for some of the cases of hæmoptysis and render the patients more susceptible to tuberculosis and pneumonia. They are destroyed by treatment with acids, and therefore in the ordinary process of examining for acid-fast organisms would escape detection.

S. hæmatobium is prevalent in Egypt, in Central and East Africa, and throughout the greater part of South Africa. It occurs in places on the West Coast, but is less common than on the East Coast. It also occurs in Arabia, in some of the islands near Africa, and in a few places in the West Indies.

Army Statistics.—After the Transvaal War many of the soldiers suffered from the disease, and carried it with them to England, India, and other places.

Persistence of Infection.—The disease may persist for years after the patients have left an area where it is endemic. As a rule the symptoms gradually become less severe; failing this, the patient pays less attention to the less important symptoms. Hæmaturia may persist after the ova cease to be passed and there is the possibility of general fibrotic changes in the kidneys.

With this worm, as with many others, more careful investigation has shown that the prominent local symptoms are not the only ill-effects of the parasite. An irregular fever with vague discomfort in various parts of the body is common in the early stages. Turner, in South Africa, has shown that the eggs may be widely distributed, and are quite common in the lungs. They may also be found in the liver and elsewhere.

Diagnosis.—This is readily made by examining the mucus discharged *per rectum* or by the urethra, as the large eggs with a sharp spine containing the fully

developed embryo—miracidium—are characteristic. In examining the urine the mucus and eggs may only be found in the urine squeezed out of the bladder after it has been previously nearly emptied by micturition. It is well to remember that the patient may also have a vesical calculus.

The presence of these eggs distinguishes this disease from other forms of hæmaturia.

Treatment.—There is no method of destroying or removing the worms, situated as they are in the blood-vessels. In exceptional instances adult worms have been found free in the intestines. These probably have passed through the liver, and as long as they are alive and sexually active eggs will be passed. Treatment, therefore, can be only palliative. In severe cases rest in bed is essential.

Bland diuretics, especially those with a sedative effect upon the mucous membrane of the bladder, are indicated ; such as buchu, with alkaline carbonates, boracic acid, or best of all urotropine, in 5-gr. doses twice daily. Oil of male fern and other anthelmintics in some cases appear to produce a temporary improvement. Possibly they may limit the fecundity of the female and fewer eggs will then be passed. Methylene blue has been advocated by some, but is worse than useless, as it may cause renal trouble. Salvarsan does not have any good effect. In the rectal condition the bowels must be kept loose, with mild, non-irritating aperients such as paraffin, and every effort made to prevent pelvic congestion. The papillomata, if they cause any trouble, may be removed : sometimes the adult worms may be found inside them. The patient must leave the endemic area if possible.

Prognosis.—The prognosis is good. The direct and indirect mortality amongst Europeans removed from the endemic area is less than 1 per cent., and the amount of tuberculosis does not differ greatly from the average. The disease may last for years, as the symptoms usually diminish in severity and ultimately cease. Major

Harrison has shown that, from an analysis of 466 cases acquired during the Transvaal War, in 37 all signs of disease ceased in less than 7 years, and the earliest that can be hoped is 5 years. In 164 cases blood and ova were continuously present, including 5 in which the disease had lasted 13 years, 16 for 12 years, and 57 for 11 years.

Etiology.—Very little is known of the development of the *Schistosomum hæmatobium*. The incubation period seems to be a short one, as symptoms have appeared in from one to two months after bathing in ponds believed to be infected. The eggs passed in the urine or with the fæces already contain the miracidium, or ciliated embryo. This is only set free when the urine or fæces are freely diluted; the ciliated embryo then bursts through the shell and becomes actively motile. It can live in water for two or three days, rather longer in thick mud, but ultimately dies without further development.

An intermediate host may be necessary, but it has not yet been discovered. Looss suggests that man himself may be the intermediate host, that the miracidium develops in him possibly in the liver. In this case he may possibly reinfect himself.

It is also unknown how man becomes infected; the infection is probably through water, but whether through the alimentary canal, by drinking water, or in bathing, by entrance through the skin, or even through the edges of the anus or urethra, is uncertain. Experiments on cats by the Japanese with the *Schistosomum japonicum* appear to show that the miracidia penetrate the skin and that the worm then develops in the cat. Immersion of cats in water fouled with excrement containing mature eggs is followed by infection of these cats though they are so confined that it is impossible for them to drink the fluid. According to this no intermediate host is required, but the stages in the development have not been traced. Infection in Europeans seems to follow snipe shooting when wading in padi fields, manured with human excre-

ment as is the rule. Dogs, cats, and other animals are frequently infected with *Schistosomum japonicum*.

Prophylaxis.—We know too little on the subject for any rational attempts at prophylaxis. In countries where the disease is endemic, micturition or defæcation into water should be prevented as far as possible. It would be well to avoid the use of water both for bathing and drinking derived from any source frequented by natives. The general opinion rather favours the view that infection is acquired by man whilst bathing. This opinion is supported by the observation that in Cape Colony the girls are rarely infected, whilst the boys are commonly so. They use the same drinking water, but the boys only bathe in the rivers. On the East Coast, where the women do the washing, standing in the water or wet mud of the streams and ponds, they are as often infected as the men.

A question that has excited a good deal of interest is whether or not two species of worms are included under the description *Schistosomum hæmatobium*. Bilharz observed that in the fæces the spine on the egg-capsule was often lateral instead of terminal. In the urine the eggs passed all have terminal spines; in the fæces, in most cases, particularly when the eggs are distributed throughout the fæcal mass, the spines are lateral. In some cases only eggs with lateral spines are passed, in others both may be present. The eggs with the lateral spine are not immature or undeveloped, as they contain a living miracidium. Either form of egg may be found in the adult female worm.

The geographical distribution of the two does not quite correspond even in Africa, whilst in South America and the West Indies the lateral-spined egg in the fæces is moderately common, and it is not certain if the terminal-spined egg occurs. Endemic hæmaturia from infection with Schistosoma is unknown in the West Indies and South America.

The balance of evidence is in favour of the presumption that there is a second species which passes eggs with a

lateral spine ; these eggs are never passed through the walls of the urinary tract, and are usually passed sufficiently high up in the intestine to be intimately mixed with the fæces. This hypothetical worm Sambon names *Schistosomum mansoni.*

Schistosomum japonicum is somewhat smaller than *S. hæmatobium.* The males are 10·5 mm. in length and 0·53 mm. in breadth, and the females 12 mm. in length and 0·4 mm. in thickness. The acetabulum is relatively larger, and the dorsal surface of the male is smooth and not tuberculated or spinous as in *S. hæmatobium.* (Fig. 20.)

S. japonicum is found in the blood-vessels of the portal system, and especially in the mesenteric vessels. The eggs are found in the liver, lymphatic glands, and intestinal submucosa, and in these situations may be found in enormous numbers. In the submucosa of the vermiform appendix they may be numerous, and cause much thickening. They have no spine, but there is a lateral thickening surmounted by a small knob which probably represents the spine, and are discharged by the intestine in the fæces, and when passed the eggs contain the miracidium, or developed embryo.

The worm is common in some districts of Japan, and occurs in China. It has been found in Chinese in the Straits Settlements, and in the Philippines, but is probably not indigenous in those countries.

It is a common parasite of cats in Japan, and was first described by Katsurada in Japan, and independently by Catto in Singapore, in 1904.

Little is known of the life-history or intermediate host, if any, of the parasite. In man, as the eggs are passed in the fæces they must escape by the intestine or the bile-ducts. What becomes of those in the lymphatic glands is unknown. Wherever the eggs are deposited they set up considerable tissue change with formation of masses of embryonic fibrous tissue. In the intestines this shows itself as thickening of the walls. In the liver, pale fibrous patches are formed, and the lymphatic glands are much enlarged and dense and fibrous. There is no pus

formation, caseation, or necrosis. The walls of the vessels containing the worms are much thickened, so that it is difficult to say whether they are veins or arteries. According to the Japanese an endemic disease characterized by enlargement of the liver and spleen with ascites is caused

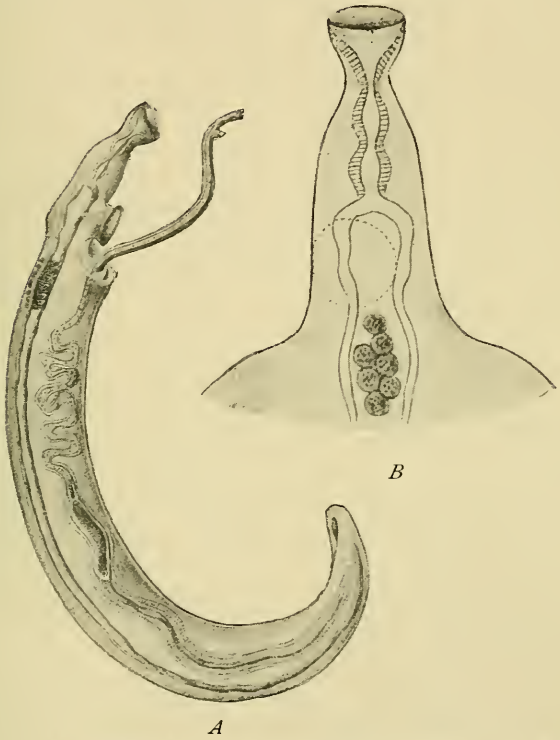


FIG. 20.—*A*, *Schistosomum japonicum*. (After Fullerton.) *B*, anterior extremity of male, enlarged.

by this parasite. In the early days of the infection there is more or less fever of an irregular type. Eosinophilia is marked in this stage and urticaria is so frequent that the fever was described as "urticarial fever" before the relation to Schistosomum infection was known. It was also in Japan known as Katayama disease. There is usually diarrhœa, and sometimes blood and mucus are passed. Later the fever may cease, and in bad cases organic changes supervene, or the urticarial fever may

be the only symptom and steady permanent convalescence occur. Death may occur from cachexia and anæmia. The fatal cases in Singapore died of intercurrent disease. The eggs in size and shape are not unlike ankylostome eggs. The numerous yolk-masses in the eggs as seen in the tissues should distinguish them from any of the nematode eggs, and in the fæces the presence of a ciliated embryo, which is liberated on the addition of water, would probably prevent any mistake.

General Effects of Trematode Infections.

Increasing observation is showing that trematode infections are of more importance and more general in the Tropics than was thought formerly. The fact that lesions are produced even if no direct symptoms are caused cannot be ignored.

General Prophylaxis.

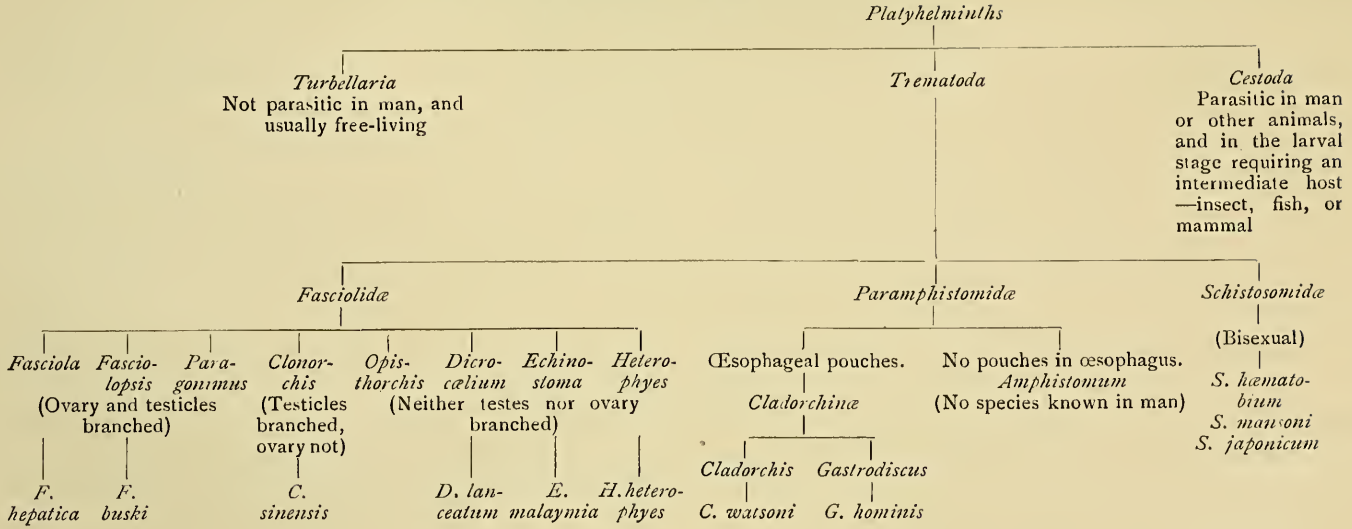
The detailed knowledge of the life-history of the intermediate hosts, if there are any, would be of great value and show the lines on which prophylactic measures should be based. Thrifty races like the Chinese are not likely to abandon the use of human excrement as manure, and the measures that can be economically adopted in the preparation of the human excrement as manure do not destroy the eggs in all cases.

Only the first stage, the escape of the miracidium, in the development of the Schistosomidæ is known, and there is no sufficient reason to assume that a mollusc is the intermediate host, if there is any. That assumption of an intermediate host, mollusc or fish, is justifiable in the Fasciolidæ.

An examination of the snails and fish in padi fields is required to find the species of the intermediate hosts.

It is in the liver of the snails that the rediæ develop, so that by breaking off the apex of the shells and teazing out the liver of the snails, the infection can be detected on microscopic examination. The species of snail or fish and its life-history should also be determined.

Table of the Important Genera of Trematodes.



Trematodes Parasitic in Man.

	Length	Breadth	Suckers	Situation	Hosts	Geographical distribution
Fasciola hepatica	20-30 mm.	8-13 mm.	The suckers nearly equal	Biliary canals	Sheep and other animals. Man very rarely	Widely distributed.
Fasciolopsis buski (*Distomum crassum*)	35-75 ,,	14-20 ,,	Ventral sucker much the larger. The two suckers are very near each other	Small intestine	Man, pig	China, India.
Paragonimus westermani (*Distoma ringeri* or *pulmonale*)	8-10 ,,	4-6 ,,	Both small	Lungs, &c. ...	Man, tigers, tiger cats, &c.	China, Japan.
Clonorchis sinensis (*Distoma sinense*)	15-18 ,,	3-4 ,,	Two suckers do not differ greatly in size	Biliary canals	Man	China, Japan, India.
Opisthorchis felineus ...	8-11 ,,	2-2·5 ,,		Biliary canals	Dog, cat. Found in man	Siberia.
Opisthorchis noverca (*Distoma conjunctum*)	9-12 ,,	2-5 ,,		Biliary canals	Fox, dog, man... ...	India.
Dicrocœlium lanceatum (*Distoma lanceolatum*)	8-10 ,,	1·5-2·5 ,,		Biliary canals	Sheep. Very rarely man	Widely distributed.
Echinostoma ilocana ...	4-6 ,,	1-1·35 ,,	Ventral sucker nearly three times as large as the oral sucker	Intestine ...	Man	Philippines.
Heterophyes heterophyes (*Distoma heterophyes*)	1-2 ,,	·7 ,,	Anterior sucker very small; ventral sucker large	Intestine ...	Man	Egypt. China, Japan.
Watsonius watsoni (*Amphistomum watsoni*)	8-10 ,,	4-5 ,,	Posterior sucker large. Small anterior sucker, but well-marked pharyngeal pouches	Small intestine	Man	Nigeria.
Gastrodiscus hominis ...	5-8 ,,	3-4 ,,	Posterior sucker much the larger. The genital pore is nearer the anterior sucker	Large intestine	Man, dog	India.

CHAPTER VI.

HUMAN TAPEWORMS.

Cestoda, or Tapeworms, differ from the Trematoda in that (1) there is no alimentary system, food being derived by absorption through the cuticle; (2) there is a single fixative apparatus situated at the anterior extremity of the body; and (3) they are divided into segments, each segment being a distinct hermaphrodite animal. There is a common nervous, circulatory (water vascular) and muscular system. They are easily distinguished from trematodes by their length, flattened, tape-like appearance, and by the segmentation.

The Cestodes are divided into two great classes, represented by the *Pseudophyllidiæ* (*Dibothriocephaloidea*) and the *Cyclophyllidiæ* (*Tæniidæ*). This separation was made on the differences of cephalic armature. That of the Pseudophyllidiæ consists of two slit-like, elongated depressions, and of the Cyclophyllidiæ of four round suckers, and a rostellum, with, in some cases, hooklets in addition.

The separation is a sound one, and can equally be made on the life-history, particularly the method of development. The development of the Dibothriocephaloidea is comparatively simple: the embryo contained in the egg becomes the larva, and this larva forms the scolex of the adult, whilst in the Cyclophyllidiæ the embryo is converted into a cyst, and the embryonic head is lost. In the interior of this cyst one or more secondary larval heads are formed, so that asexual multiplication may occur. These larval heads, produced asexually, become scolices of the adults and the embryonic head

disappears when the cyst is formed, and does not become the scolex of the adult.

The structure of the Cestodes resembles in many points that of the Trematodes. The adult Cestode consists of a head—*scolex*—which is armed with fixative structures—by which it is attached to the intestinal wall of its host. This scolex contains the ganglionic nerve-mass and the commencement of the water vascular system. The fixative apparatus consists of two long, slit-like suckers in the Dibothriocephaloidea, or of four round or oval suckers in the Tæniidæ, and in these there is also a terminal conical retractile mass—rostellum.

Dibothriocephaloidea.

The Dibothriocephaloidea.—The scolex is long and narrow, there is no rostellum, and no other armature but the elongated suckers, or bothridia. The genital pore opens on the flat surface of the proglottis. The uterus is much coiled, forming a kind of rosette in the middle of the worm, and has an external opening posterior to the genital pore. The testicles are numerous and arranged laterally, anterior to the vitellaria—yolk-glands—which are also lateral.

The eggs are enclosed in a shell which, like the eggs of the Fasciolidæ, has an operculum. When the eggs are passed the ovum is immature and surrounded by yolk. An embryo with six hooks forms and round it a capsule—embryonic capsule—which is ciliated. The embryo and capsule together form the *oncosphere* (fig. 21, *b*). When this development is complete the ciliated embryo escapes, and after a short free life enters an intermediate host, usually a fish. In these features the bothriocephalus resembles a trematode, but differs from it in that in the interior of the ovum there is a formed embryo, the head of which forms the head of the mature worm. The outer portion carrying the cilia is quite separate.

Entering the intermediate host, this outer envelope disappears, and the embryo is set free, passing through

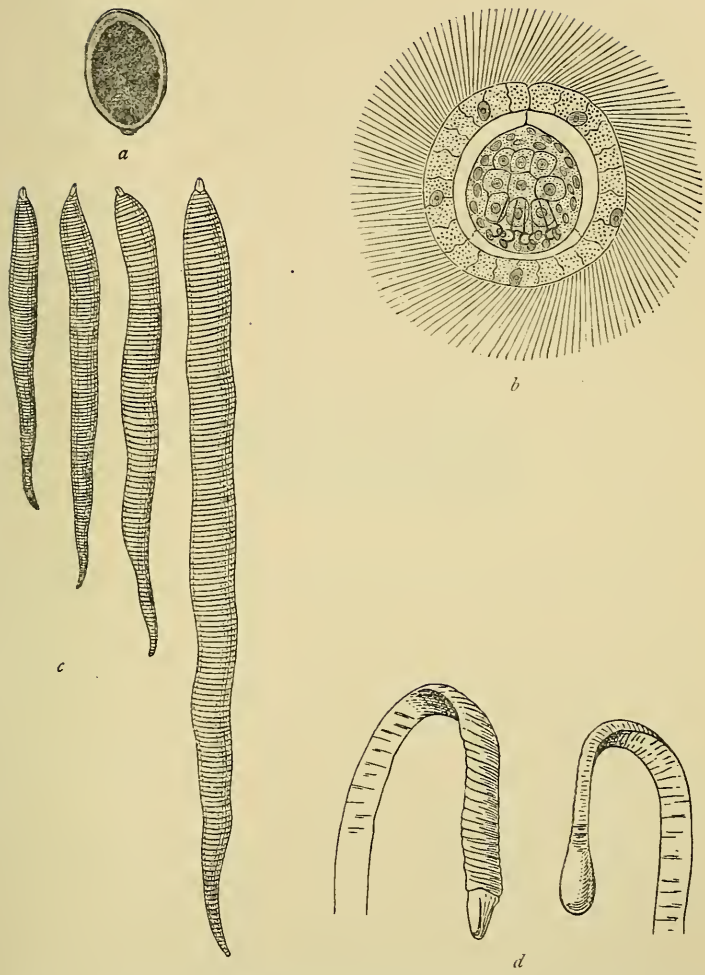


FIG. 21.—Stages in development of Bothriocephalus. *a*, ovum; *b*, oncosphere; *c*, plerocercoid larvæ; *d*, head of mature Dibothriocephalus, lateral and ventral aspect.

the intestinal wall, losing its hooklets and developing into the larval form in the muscles and tissues of the host. It there grows, develops the bothridia, and becomes an elongated, unsegmented worm-like body—the plerocercoid larva (fig. 21, *c*). When this larva is swallowed with the flesh of the host—fish—by the definitive host—man—the larva is set free and attaches itself to the intestinal wall and develops into the adult form.

The genera into which the Dibothriocephaloidea are divided are not numerous.

(1) *Dibothriocephalus*.—The type of the order, in which each proglottis has a single complete sexual apparatus consisting of two ovaries, testes, and a single genital pore, and single uterus with its uterine opening.

The species found in man is the *Bothriocephalus latus*, and in the Arctic regions other bothriocephali are found in dogs, in seals and other fish-eating mammals. Some species are found in the Tropics in dogs, and in man in Japan.

The *Bothriocephalus latus* is not usually a tropical parasite, as it is most common in Arctic and sub-Arctic regions, as Lapland, Finland, Iceland, around Swiss lakes, &c. In many parts of Germany it is also common. It occurs in Japan. In all cases it is associated with the consumption of imperfectly cooked fish.

The interest in connection with this parasite is the occurrence of anæmia of an intense form in some of the persons harbouring the parasite.

Drugs, such as iron and arsenic, have little or no effect on this anæmia, but rapid improvement and complete recovery result from the removal of the parasites.

As this worm, though it fixes itself on to the intestinal wall, does not live on blood, but entirely on the food absorbed from the intestinal contents, the anæmia produced must be due to some toxin formed and excreted by the parasite, and absorbed by the host from the intestinal contents. Fatty substances have been isolated from the bodies of these worms which produce anæmia

when taken by the mouth. Eosinophilia is not marked in infections with this worm.

(2) *Diplogonoporus.*—In these there are two complete sets of sexual organs in each proglottis, so that there are two genital pores, and posterior to each a uterine opening. Two pairs of ovaries and two distinct uteri.

Diplogonoporus grandis, found in Japan, but is rare. It is a very large tapeworm, up to 10 or 12 yards in length. The structure of the head is unknown. The segments, even when mature, are very broad in proportion to their length, 14 to 16 mm. in breadth, about 0·5 mm. in length. The arrangement of two complete sexual organs on each

FIG. 22.—Head of plerocercoid larva (*Sparganum*). (Aboriginal of British Guiana.)

side of the middle line gives the appearance of two streaks running along the flat surface of the worm. Symptoms similar to those caused by *Bothriocephalus latus* are said to occur.

Another species, *Krabbea grandis*, in which the uterine opening is on the opposite side to the genital pore, has been described. This is a very rare species.

For these species man is the definitive host, as he harbours the parasite in its sexual or adult form.

There are three known species of larval parasites, probably the plerocercoid larvæ of Dibothriocephaloidea, that have been found in man. Such forms are now placed in a separate group, *Sparganum*, but when the adult forms are known they will be placed in their proper groups.

Of the larval forms, *Sparganum mansoni* is fairly common in Japan and China. They are usually found in

sub-connective tissue. They are feebly motile, worm-like bodies, and 30 to 35 mm. in length and about 5 mm. in breadth. They show transverse wrinklings, not true segmentations, and are flattened.

In a British Guiana aboriginal, a large Sparganum, 8 in. long, was found in the connective tissue in the posterior mediastinum. It differed from *S. mansoni* in shape. As it is so much larger it is probably a distinct species.

A third species has been received from Uganda.

No systematic disease is known to be associated with these larval forms, but when in the subcutaneous connective tissue they may give rise to indolent tumours which persist for prolonged periods. In rare cases suppuration may occur and lead o the formation of an abscess. The parasites have been known to be passed by the urethra.

CHAPTER VII.

CYCLOPHYLLIDIÆ.

Cyclophyllidiæ (Tæniidæ).—Several species are found in man and two of them are common. Man is for one species—Echinococcus—only the intermediate host. In the other—*Tæniidæ*—he is the definitive host; in some, as *Tænia solium*, though usually the definitive host, and infected with the sexually mature worm, he may harbour larval forms—*cysticerci*—and, therefore, can act also as the intermediate host for that species.

The Cyclophyllidiæ differ from the Dibothriocephaloidea in the course of development as well as in the structure of the scolex and proglottides.

The eggs are either passed from ripe proglottides whilst still in the intestinal canal of their host, or are deposited by the proglottis on the ground, or in water, after the ripe segment has escaped from the intestine.

These eggs at the time they are passed have lost their outer part, so that only the embryo in its embryonic capsule—*oncosphere*—is to be seen.

It is a part only of the egg, and not, as is commonly supposed, the tapeworm egg. Remnants of the remainder of the egg sometimes may be seen still attached to the capsule of the oncosphere.

The embryo at the stage which it has reached when the oncosphere is passed has a definite head and is armed with three pairs of nearly straight hooklets.

The embryonic capsule is thick and in many cases striated radially. The cells covering the oncosphere, if any remain after the "egg" is passed, soon disappear and the embryo remains quiescent in its capsule.

When these oncospheres are swallowed by a suitable intermediate host—man or sheep in the case of *T. echinococcus*, or by a lepidopterous insect as in *Hymenolepis nana*, by cattle as in *T. saginata*, or by pigs as in *T. solium*—the embryonic capsule is dissolved and the embryo with its armed head is set free. It penetrates the intestinal wall, and travelling with the blood-current or otherwise, soon reaches an organ or situation suitable for its further development. The liver, peritoneum, lungs, &c., and muscular system, are favoured places, but no organ, not even the brain, is free from possibility of invasion.

In such a situation the embryo becomes motionless, and soon globular and cystic, the hooklets being spread out over the outer surface of the cyst or dropping off. This—the *cysticercus*—soon becomes a definite cyst, and from the germ cells lining this cyst scolices are produced. In the echinococcus secondary cysts are formed, and in these, the daughter-cysts, scolices may be found. This asexual multiplication may go on indefinitely, so that large cystic tumours may be found, as in the well-known hydatid cyst—the cysticercus of *T. echinococcus*. From one egg many scolices, and therefore many adults, may result.

The cysticerci, when ingested by a suitable host, are partially dissolved, the scolices set free, and each scolex may attach itself to the intestinal wall of its new host, and form the head or scolex of an adult tapeworm. The adult cyclophyllidiæ differ not only in the structure of the head and in their development, but also in the arrangement of the genital organs present in each segment.

The opening of the male and female organs is lateral, at the thin margin of the proglottis. The testes are scattered through the parenchyma and the ducts from them lead into a single tube, terminating in a cirrhus pouch at the genital pore.

Close to this opening is that of the vagina, which at first runs towards the middle line, and then bends laterally,

dilating into a vesicle which acts as spermatheca. The ovaries are on each side of the tube, and round the tube are the shell-glands. Posteriorly are the vitellaria or yolk-glands, and the ducts from these also open into the dilated portion of the vagina. The ova are therefore fertilized, and receive their yolk and thin shell in the terminal part of the vagina. They are not discharged through the vagina, but pass into a diverticulum from it which runs

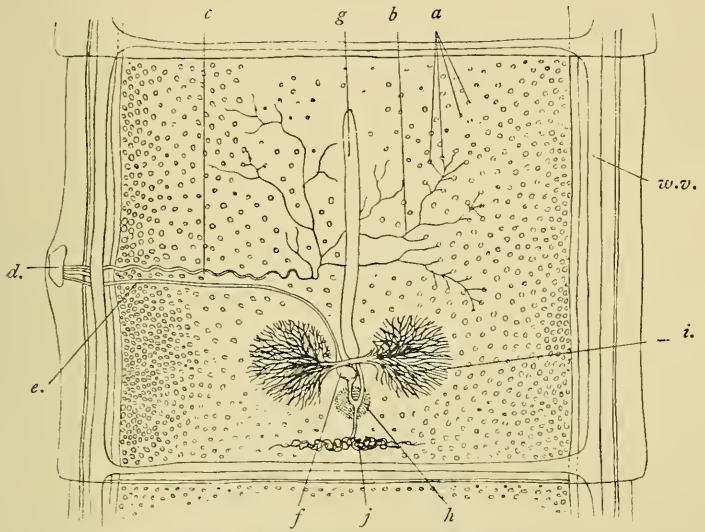


FIG. 23.—*a*, Testes; *b*, vasa efferentia; *c*, vas deferens; *d*, genital pore; *e*, vagina; *f*, receptaculum seminis; *g*, uterus; *h*, shell-gland; *i*, ovary; *j*, vitellaria or yolk-glands; *w.v.s.*, water vascular system.

along the length of the proglottis (fig. 23). As the eggs accumulate lateral pouches are formed in the diverticulum which is known as the uterus. In the cyclophyllidiæ the uterus has no natural external opening.

The classification of the Cestodes occurring in man is based on the character of the scolex, the development of the embryo, and the arrangement of the genital organs. In Cyclophyllidiæ the genital pores are at the edges, in the Pseudophyllidiæ on the flat surface (fig. 24).

Dipylidium.

Dipylidium is a genus in which the genital organs are duplicated. As in all the Tæniidæ, the genital pore is lateral, and the two sets of genital organs open on to the opposite edges of the proglottis (fig. 24, B). The common dog tapeworm, *Dipylidium caninum*, belongs to his class.

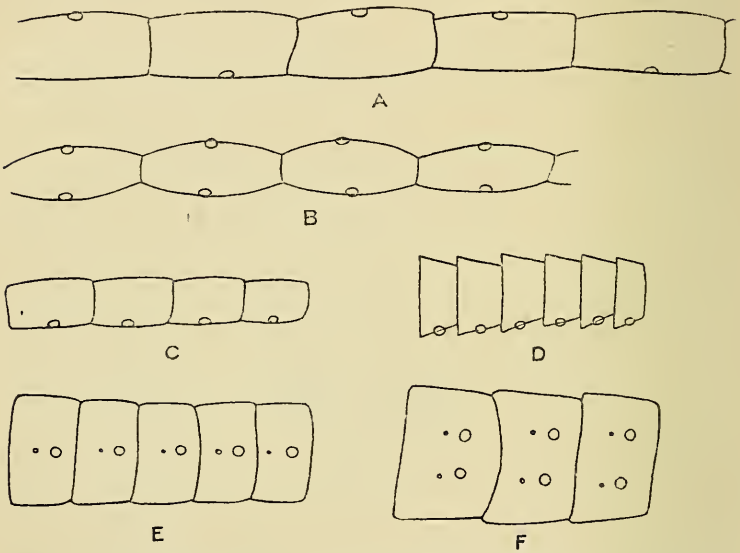


Fig. 24.—A, *Tænia saginata;* B, *Dipylidium;* C, *Davainea;* D, *Hymenolepis;* E, *Bothriocephalus;* F, *Diplogonoporus grandis.*

Dipylidium caninum is an accidental parasite of man, and though not very common is found all over the world, and perhaps more commonly in the Tropics than elsewhere. Only children seem to acquire the infection. In these cases the segments are nearly always passed singly with the motions, and on account of their small size and active movement their nature may not be recognized. They do not seem to cause any symptoms and are readily expelled by anthelmintics.

As the cysticercoid stage is passed in the dog-flea and

other ectoparasites of the dog, too close association of dogs and children should be avoided.

In the other genera of Tæniidæ found in man there is a single set of genital organs in each proglottis. In *Hymenolepis* and *Davainea* the genital pores in all the segments are on the same side (fig. 24, C and D). These genera are readily distinguished from each other by differences in the genital organs.

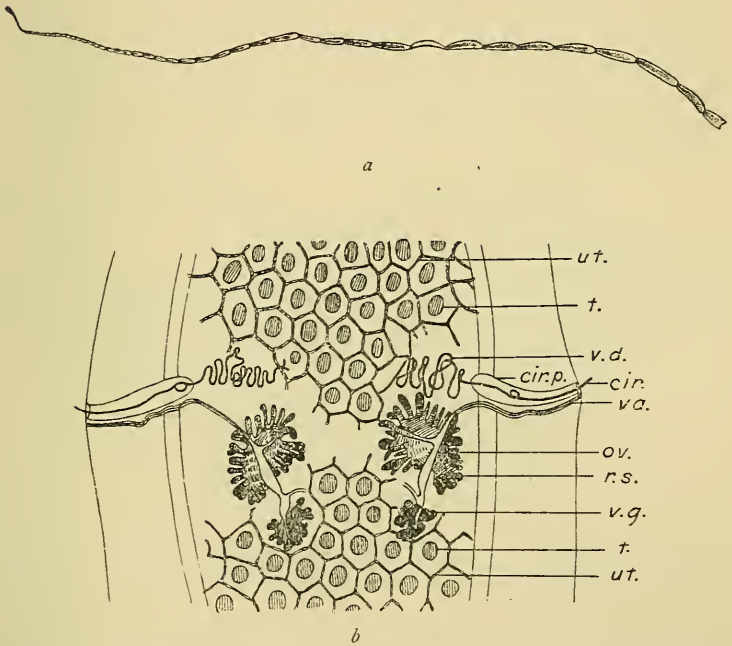


FIG. 25.—*a*, *Dipylidium caninum*; *b*, enlarged half-grown segment; *t.*, testes; *v.d.*, vas deferens; *cir.*, penis; *va.*, vagina; *ov.*, ovary; *r.s.*, receptaculum seminis; *v.g.*, yolk-gland; *ut.*, uterus.

HYMENOLEPIS.

Hymenolepis.—Testes are large but few in number, usually three or four in each segment. These are arranged on the side opposite to the genital pore, and

form a row, which is readily seen with the naked eye even in unstained specimens (fig. 27). In the mature segments the eggs are contained in the uterus, and the mature segments are broader than they are long.

Hymenolepis nana is not a very rare parasite in man. It is found in the United States of America, in Egypt, Japan, and South America, as well as occasionally in Europe. According to Foley, in Figing, Berbera, it is found more common in children. In 16 children under 5 he found it three times; out of 96 5 to 15 years old, once; and in none of 102 examined over that age. It is a very small tapeworm, 15 mm. in length, and in its broadest segments 0·5 to 1 mm. in breadth. It has about 150 segments (fig. 26).

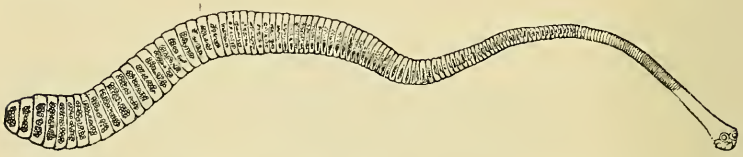


FIG. 26.—*Hymenolepis nana* (v. Sieb.). About 12/1. (After Leuckart.)

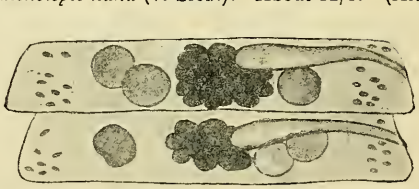


FIG. 27.—*Hymenolepis diminuta;* two proglottides slightly enlarged. The circular masses are the testes. (After Grassi.)

It is closely allied, if not identical, with *H. murina*, common in rats, and in that case the cysticercoid stage is probably passed in one of the lepidopterous moths or their larvæ, which infest stored grain. It does not seem to cause any symptoms in man. Treatment is unsatisfactory, and complete expulsion of the worms difficult. The prevention mainly turns on better storage of grain, so that rats cannot deposit their fæces amongst it, and in preventing moths having access to the grain; possibly

by improving the condition of the digestive organs, as geophagy appears to be one of the methods by which infection is acquired, and this usually results from digestive disturbances.

H. diminuta is a still smaller variety which is rare, but of wide distribution, and doubtfully a different species. The normal hosts are said to be rats and mice.

DAVAINEA.

In *Davainea* the testes are numerous, the mature segments are much longer than they are broad, and the eggs are not enclosed in the uterus, but early escape and form masses large enough to be seen with the naked eye in the parenchyma. The suckers are surrounded with small hooklets.

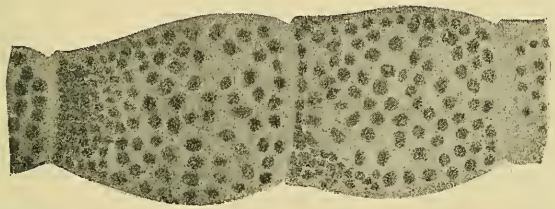


FIG. 28.—Nearly mature segments, *Davainea madagascariensis*. (British Guiana.)

Insectivorous animals such as birds are the usual hosts of both Hymenolepis and Davainea, and probably in both genera insects are the usual intermediate hosts.

Davainea are rare parasites in man, but have been found in Mauritius, Madagascar, Siam, the Philippines and British Guiana. It is not certain if all the specimens belong to the same species. They appear to cause no symptoms in the recorded cases.

The first described species in man was the *Davainea madagascariensis*, about 30 cm. in length. The mature segments are 2 mm. in length by 1·4 mm. in breadth. The egg-masses are conspicuous, and each contains a large number of eggs (fig. 28).

TÆNIA.

Tænia.—A large group, which includes the common tapeworms found in man. The openings of the genital pores are not all on the same lateral margin, but are irregularly alternate (fig. 24, A). Tests are numerous. The intermediate hosts and definitive hosts both belong to the Mammalia.

The armature of the scolex varies; in some the hooklets persist throughout adult life, *e.g.*, *Tænia solium*. In others there are no hooklets in the adult scolex, *e.g.*, *T. saginata*, and these are sometimes known as unarmed tapeworms. They all have the four suckers and rostellum.

T. solium is a large tapeworm, 2 to 3·5 metres in length. There are some 800 proglottides. The ripe proglottis is usually 10 to 12 mm. in length and 5 to 6 mm. in breadth. The uterus has about ten lateral diverticula and often less. In the younger segments the vagina passes through the ovary on the same side (fig. 32) on its way to the genital pore. The rostellum is surrounded at its base by a double circle of hooklets. It is not widely distributed in the Tropics, as the intermediate host is the pig, and therefore in Mahomedan countries man has few opportunities of acquiring the parasites. In non-Mahomedan tropical countries, such as China and South Africa, where pigs are freely eaten, this tapeworm is common. In non-tropical regions it is most common where imperfectly cooked pork is eaten, as in Germany. In many people the presence of tapeworms produces ill-health, and often a neurasthenic condition.

Man can act as the intermediate host as well as the definitive host of *T. solium*. This occurrence is most frequent where human excreta are used for manure, as in China, but may occur whenever the ova are introduced into the stomach. Auto-infection is believed to occur as a result of regurgitation of ripe segments from the intestine. The cysticercus, when it occurs in man, is often subcutaneous, and then forms a rounded visible swelling,

which can be readily removed. In other situations the cysticerci may be the cause of serious disease, as they may be found even in large numbers in the brain, eye, and heart. It is rarely found in the liver. In the brain the cysticerci usually develop in the membranes, and give rise to epileptiform attacks, which are often fatal. In the eye they may be beneath the retina, in the vitreous, or in the anterior chamber, and lead to the destruction of the organ (fig. 29). In the heart and lungs they may lead to functional disturbance.

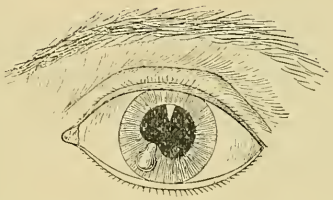


FIG. 29.—*Cysticercus cellulosæ* in the anterior chamber. (After Leuckart.)

The adult form can be recognized by the passage of mature segments. These are readily distinguishable from the ripe proglottides of *T. saginata*. If they are compressed between two slides and held up against the light it will be seen that the lateral pouches of the uterus are not very numerous (fig. 34). The proglottis is smaller and less actively motile than that of *T. saginata*. The eggs, or rather the oncospheres, may be found in the fæces when no segments have been met with.

The cysticercus is recognized in man by the shape of the hooklets, though in the human cases they are often imperfect or irregular. The cysticercus of this tapeworm is known as the *Cysticercus cellulosæ*.

T. saginata is the most widely distributed of the human tapeworms, and is larger than *T. solium*, it may measure from 4 to 8 metres, and has 1,200 proglottides or more. The mature proglottis measures on the average 16 to 20 mm., by about 3·5 mm. in breadth. The head

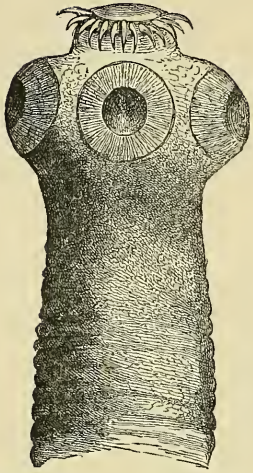


FIG. 30.—Head of *Tænia solium*. 45/1.

FIG. 31. — Cephalic end of *Tænia saginata* in the contracted condition. 8/1.

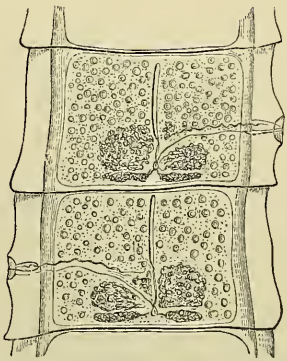


FIG. 32.—Two fairly mature proglottides of *Tænia solium*, with sexual organs and excretory vessels. Note that the vagina cuts off a small portion of one ovary.

has no hooklets, and usually there is a deposit of black pigment in the anterior part of the head, which gives a dark appearance to it as seen with the naked eye. Sometimes the amount of this pigment is so great that some specimens have been called *T. nigrocephala*.

The proglottides, when sexually mature, can be distinguished from those of *T. solium*, as the ovary on the same side as the genital pore is not perforated or divided by the vagina (figs. 32 and 33). The mature proglottides,

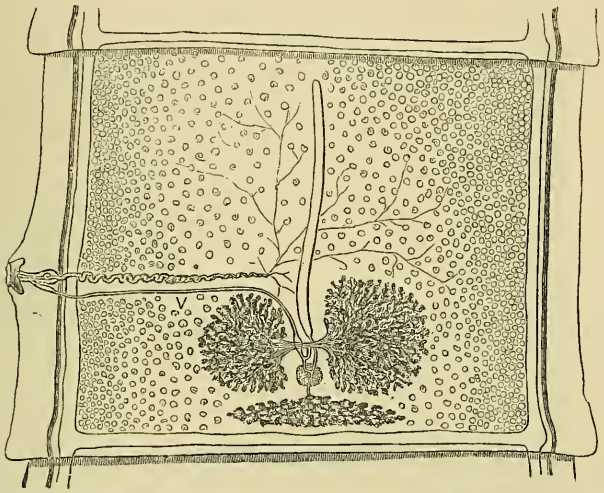


FIG. 33.—Proglottis of *Tænia saginata*, with genital organs. Note that the vagina, v, passes round the left ovary and not through it.

distended with eggs, show far more numerous (twenty to twenty-five) and much branched diverticula (figs. 34 and 35). The eggs are slightly more oval.

The cysticercoid form is found in the ox, usually in the muscles, and is known as *Cysticercus bovis*. It is about 8 mm. by 5 to 6 mm. (fig. 36). The *C. bovis* is very rare in man, if it ever occurs.

The adult form is common in the Tropics, though not more so than in Europe. The usual intermediate hosts are cattle, and in some countries, as in Abyssinia, where

raw or nearly raw beef is eaten, this tapeworm is present in almost all the people.

An important point in connection with this worm is the liability for infection to occur in persons fed on raw

FIG. 34.—Two mature proglottides of *Tænia solium* with fully developed uterus. 2/1.

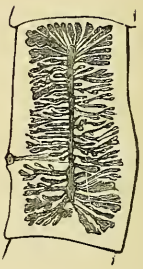


FIG. 35.—Mature segment of *Tæniæ saginata*, with fully developed uterus. 2/1.

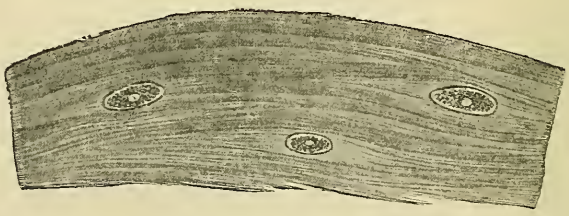


FIG. 36.—A piece of the muscle of the ox, with three specimens of *Cysticercus bovis*, natural size. (After Ostertag.)

meat, on pounded fresh meat, or even meat juice. This diet is often prescribed for persons with chronic intestinal diseases or impaired powers of digestion. The cysticerci in beef are very small, and they may easily escape notice. Though persons in vigorous health often suffer no in-

convenience from an infection with this worm, it is very different in the case of a chronic invalid, and it will invariably be found that as the tapeworm matures the patient will lose weight. The preliminary fasting and the purgation required to remove the worm are not well borne by such patients.

Varied opinions have been held as to the importance as causes of ill-health of infection with Tæniidæ. To many people the presence of such worms is a source of annoyance, and such persons will refer any ill-health or dyspeptic symptoms to these worms. Whether the disease is really caused by the worms or whether their presence merely leads to morbid feelings, the expulsion of the worm is equally imperative. In other cases the ill-health precedes the knowledge of the presence of the worm; and in invalids fed on raw meat, if they become infected, loss of weight certainly occurs.

Expulsion of the worm is strongly indicated where the condition of the patient admits of the treatment. Any purgative will cause the expulsion of immature as well as of mature segments; but as long as the scolex remains new proglottides are formed and after an interval, dependent on the length still remaining, segments will again be passed. After an abortive attempt at treatment there is usually a period of two months before mature segments are passed. The expulsion of the scolex is therefore necessary.

Treatment.—In many cases the worm is easily expelled. in others several attempts may have to be made. Probably the amount of mucus influences the result. Treatment may be divided into three stages: (1) *preliminary*, starving and purgation; (2) *anthelmintic*, oil of male fern in full doses, combined with or followed by (3) a *purgative* such as castor oil. (1) In many cases it is sufficient to keep the patient without food for twelve hours, and give a brisk salient aperient so as to act freely in the early morning, but it is better for light diet only to be taken for two or three days previously. (2) Follow

this action by the administration of one drachm of *freshly prepared* oil of male fern in gelatine capsule or emulsion with a half-an-ounce dose of castor oil; some prefer to the castor oil one minim of croton oil. If, however, this treatment fails and the segments are again passed after about two months, much more careful preparation of the patient is required.

The diet for three or four days should be light—milk puddings, beef tea, milk and soda, or milk and barley water, with only a little fish or meat should be taken. Vegetables and fruit that do not leave too hard a residue may be taken. The bowels should be kept freely open each morning with a salient aperient and small doses ($\frac{1}{10}$ gr.) of calomel taken three times a day. Some American authorities recommend podophyllin in the belief that this drug tends to remove the mucus surrounding the head of the worm. Some prefer, in addition, to give doses of ammonium chloride, 5 to 10 gr. in a wineglassful of water three times a day. By these means the mucus in which the scolex is embedded will be to a large extent removed.

On the day before the treatment is commenced the patient must be kept in bed and take very little food, and none at all after 4 p.m. The bowels must be kept freely open with salines.

On the following morning at 7, 8, and 9 a.m., half a drachm of the fresh oil of male fern should be given, and in addition, at 8 or 9 a.m., 5 drachms of the mixture so much used for ankylostomes (eucalyptus oil or eucalyptol ℥xxx, chloroform ℥xl, ol. ricini, ʒx).

The patient must be kept absolutely at rest and not allowed to sit up or raise his head. No food of any kind should be allowed till a motion has been passed, and only fluid nourishment throughout the day.

Unless the scolex be passed the treatment has probably failed. In addition to examining the motions for the scolex, and straining the stool if necessary, it is advisable to make sure that there is not more than one tapeworm.

Unfortunately, the removal of the tapeworm is not always followed by the relief of the symptoms, and in some cases such an infection is the starting point of hypochondriasis, which must be treated on ordinary lines.

Prophylaxis.—Thorough cooking of meat will destroy the cysticerci. Where raw meat has to be taken beef and pork should be avoided, as it is very difficult to examine the meat closely enough to be sure that no cysticerci are present. Raw mutton, pounded, and chicken are free from risk, as man is not the definitive host of any of the parasites of sheep or fowls. It is well to remember that the oncospheres of *T. solium* if introduced by the mouth may develop in man into the *Cysticercus cellulosæ* in the tissues as well as that the *Cysticercus cellulosæ* will develop in the intestine of man into *T. solium.*

Other Tæniidæ that have been found in man but are very rare are the *T. africana* (one case) and *T. confusa.*

Diagnosis.—The diagnosis of tapeworms is easy, as the ripe proglottides are passed with the fæces. Sometimes the oncospheres are found at times when no segments are being passed. There is usually an excess of eosinophiles in the blood.

ECHINOCOCCUS.

T. echinococcus is considered separately, as the cysticercoid form only is found in man; the adult form is found in dogs, wolves and jackals.

T. echinococcus is a small tapeworm, and usually composed of only four segments, sometimes three or five. The last segment is much the largest and is the only one containing mature eggs (fig. 37). The rostellum is prominent and swollen, and round the base are two rows of hooklets, thirty to forty in number.

In countries where dogs are numerous and live in close association with man, man is frequently infected, though sheep and pigs are the usual intermediate hosts.

In Iceland and Australia the disease is a common one, and in some parts of Europe it is not rare.

In the Tropics, where dogs are considered as unclean animals, the disease is rare, but it does occur in India and elsewhere.

FIG. 37.—*Tænia echinococcus.*

The cysticercus of the parasite may attain enormous dimensions, as in man secondary cysts—daughter-cysts—are formed in the interior of the primary cyst in great profusion (fig. 38). This formation of cysts may continue for years, whilst many of them are barren and

do not contain scolices. The commonest situation for these tumours is in the liver, but they are not uncommon in the peritoneum, lungs, brain and elsewhere.

The adult tapeworm grows and matures rapidly, the full development, from the time the scolices are ingested by the dog to that in which the terminal segment becomes mature and eggs are passed with the fæces, is only forty days.

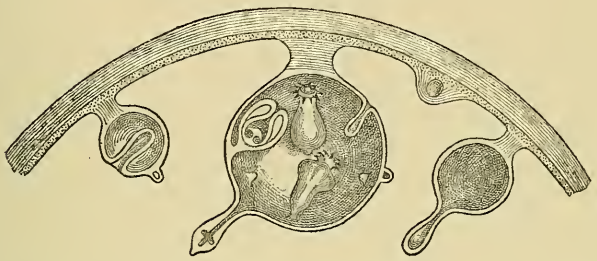


FIG. 38.—Section through an *Echinococcus* cyst with brood-capsules. (From a wax model.)

The eggs may be deposited on vegetables, and it is probable that this is the common way in which infection occurs in man in Australia, but where dogs are kept about a house there are many ways in which the eggs may be ingested by man. The time required for the development of the cysticercoid tumours is much longer; two or three years is a comparatively short period, and the tumour may continue to increase for many years.

Treatment is necessarily surgical. Aspiration is not advisable; the cyst should be opened and drained. Very strict antiseptic precautions are necessary, and as there is usually no immediate danger it is advisable that such operations, whether on the liver, lungs, or brain, should only be undertaken where such precautions are practicable.

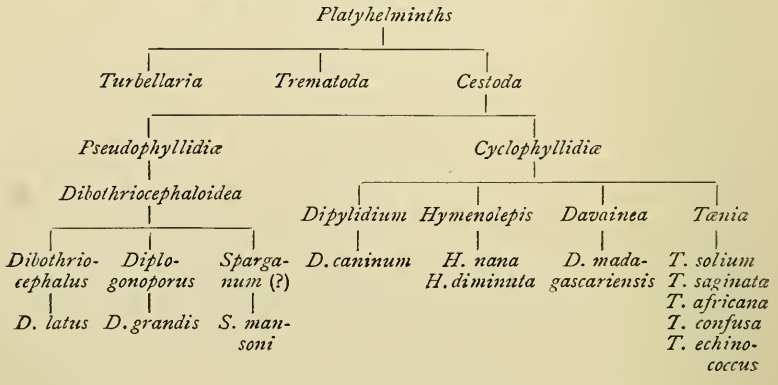
The diagnosis has to be made from other tumours in the same regions. It is only when the cysts are in contact with the parietes that the "hydatid thrill" can be obtained, or that we can be sure of the fluid nature of the tumour.

Aspiration with an exploring needle or a large hypodermic syringe is often conclusive, but should not be done unless all preparations for the completed operations have been made. The proofs obtained are: (1) fragments of the laminated membrane may be found; (2) detached hooklets or even a complete scolex may be obtained; (3) if clear fluid be drawn off, free from albumin and of low specific gravity, 1010, it is highly suggestive. The proceeding is not free from risk, as sudden death may occur. The puncture in some cases leads to rupture of the cyst, if in the liver into the peritoneum, or if in the lungs into the bronchi. Smart attacks of urticaria may follow such explorations, or even death, due to the absorption of the toxins in the fluid within the cysts or in fluid that has escaped from the cysts. Possibly the grave results are essentially anaphylactic.

The use of X-rays has greatly facilitated the diagnosis of these cysts, so that such exploratory measures are rarely needed now for diagnosis and should not be made.

Prophylaxis includes registration of dogs, destruction of butchers' offal, and prohibition of dogs in any slaughterhouse. It is important to thoroughly cleanse such vegetables as are eaten raw, and it is advisable to drink only boiled water, as the oncospheres may be blown into drinking water.

TABLE OF TAPEWORMS FOUND IN MAN.



CHAPTER VIII.

NEMATHELMINTHS.

Nemathelminths are round, unsegmented worms, as a rule tapering at both ends. There is a body-cavity, but without any epithelial lining. Sensory organs, such as papillæ in the neighbourhood of the mouth, and genital openings are present, and eye-spots may be found in allied free-living species. The nervous system varies, but in all there is an anterior and a posterior nerve ring with longitudinal dorsal and ventral nerve trunks. These trunks have lateral branches which may form complete rings.

In most species there is a complete alimentary canal, with mouth, intestine, and anus.

The sexes are distinct: the male organ, always a single testis, opens into the rectum, forming a cloaca, and there are copulatory spicules. The female organs, usually two ovaries, unite into a single tube—vagina—which opens separately from the alimentary canal.

The nemathelminths are often parasitic during a portion of their lives only. Some are parasitic throughout the whole of their existence, and in such cases the larval and adult, sexual, stages are frequently passed in different hosts. There are three classes :—

(1) *Nematoda.*—With mouth and alimentary canal; longitudinal unstriped muscles only are found. There is a single testicle and vas deferens which opens into the rectum. Important parasites of man and the domesticated animals belong to this class.

(2) *Nematomorpha* are parasitic in their larval stages in aquatic larvæ, insects, &c., and in their adult stage are

free-living in water. The alimentary canal is usually degenerate.

(3) *Acanthocephala* have no mouth or alimentary canal. They have a protrusible proboscis, covered with numerous rows of hooks. They are common parasites in birds, but have been found parasitic in man. They are more likely to be mistaken at a superficial examination for Cestoda than recognized as Nematoda.

Nematoda.

Nematoda are a very large class including free-living forms, forms living in decaying vegetable matter, and forms parasitic not only in invertebrates and vertebrates but in plants. The life-history varies greatly in the different families. The Nematoda parasitic in man belong to the families :—

(1) Anguillulidæ, *e.g.*, *Rhabdis.*

(2) Angiostomidæ, *e.g.*, *Strongyloides intestinalis.*

(3) Filariidæ, *e.g.*, *Filaria bancrofti*, *F. loa*, *F. perstans*, *F. medinensis*, and *F. volvulus.*

(4) Trichotrachelidæ, *e.g.*, *Trichocephalus trichiurus* or *dispar*, and *Trichina spiralis.*

(5) Strongylidæ, *e.g.*, *Ankylostoma duodenale*, *Necator americanus*, *Triodontophorus diminutus*, *Œsophagostomum apiostomum* (*vel brumpti*).

(6) Gnathostomidæ, *e.g.*, *Gnathostoma siamense.*

(7) Ascaridæ, *e.g.*, *Ascaris lumbricoides*, *A. mystax*, and *A. caninum*, and *Oxyuris vermicularis*, *Physaloptera mordens.*

The separation into families is based on several different characters. Amongst these the most important are (1) the character of the mouth and œsophagus; (2) the arrangement of the genitalia, and especially of the male genitalia ; (3) the life-history ; (4) the general characters.

Anguillulidæ.—All small worms. The head is not provided with any armature and there is a double dilatation of the œsophagus in the adult form.

They are rarely parasitic in man and only during a portion of their lives—the larval stage. The females have long pointed tails. Many of the other families of the Nematoda in their larval stage closely resemble the Anguillulidæ. Such larvæ with a double dilatation of the œsophagus are known as rhabditiform larvæ.

Two species of Anguillulidæ have been described in man. *Rhabditis pellio*, found in the vagina, and *R. niellyi*, found in pustules in the skin, but these were immature and possibly were rhabditiform embryos of some species belonging to another family of the Nematoda.

The better-known Anguillulidæ are parasitic on plants.

Angiostomidæ have a simple unarmed mouth, and in the mature parasitic form a very long œsophagus without a double dilatation. The method of development in this group is peculiar and characteristic, as sexual maturity is attained alternately in the parasitic and in free-living forms. These parasitic and non-parasitic sexual forms do not resemble each other. The alternation of generations between sexual maturity as a parasite and sexual maturity as a free-living form, and the marked difference in the characters of the worm when parasitic and when not parasitic are highly characteristic. Several species are known in the lower animals, and one in man, the *Strongyloides intestinalis*.

Strongyloides intestinalis—syn. *Anguillula intestinale e stercorale Rhabdonema intestinale*—is a very common intestinal parasite in the Tropics; it is found in Asia, Africa, and America, in the South Pacific Islands and the West Indies.

The adult parasitic form is 2·2 mm. in length and 0·034 mm. in breadth. It is nearly cylindrical and is found in the mucosa and on the surface of the mucosa in the small intestine, and is most readily found on examining scrapings of the mucosa. When there are pouches in the intestinal wall these parasites are usually to be found in large numbers in them. The mouth has four lips, the œsophagus is nearly a quarter the length of the body,

and the anus sub-terminal. The tail end is pointed. The female genital orifice is in the posterior third of the body. In the uterus a few eggs only are found, and as these are

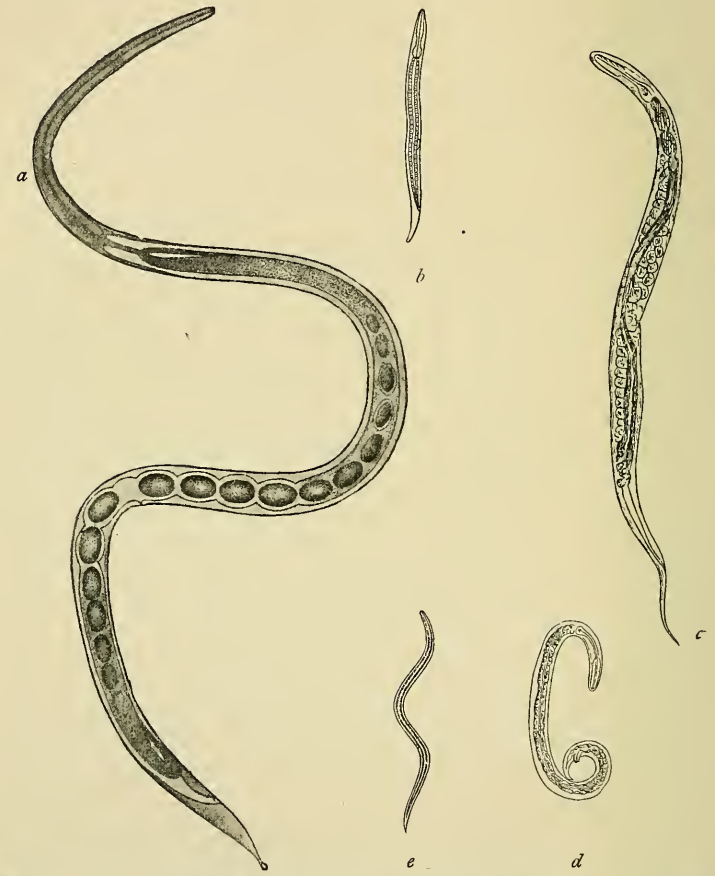


FIG. 39.—*Strongyloides intestinalis*. *a*, mature parasitic form; *b*, rhabditiform larva; *c* and *d*, sexually mature free-living female and male; *e*, filariform larva.

0·05 mm. in length and 0·03 mm. in diameter, they appear to completely occupy the central part of the body (fig. 39).

Males have not been found, according to most observers, but Smith claims to have found adult males. His observation has not been confirmed. Possibly in this generation parthenogenetic reproduction takes place.

The free-living generation is different in all characters. Both male and female forms are known.

The females are 1 mm. in length and 0·05 mm. in breadth. The mouth has four lips and a short œsophagus with a double dilatation. Anus sub-terminal. The tail end is straight and pointed. The eggs are thin shelled, 0·07 mm. in length and 0·045 mm. in breadth.

The males are smaller, 0·7 mm. in length and 0·045 mm. in breadth. The tail end is coiled up, the cloaca is sub-terminal, and the two spicules are equal, small, and much curved.

The life-history is of special interest. The parasitic form deposits its eggs in the intestinal mucous membrane, or in the crypts in it. The eggs develop into larvæ which increase in size and pass into the lumen of the intestines, and leave their host in the fæces. At this stage they show the double dilatation of the œsophagus. In the fæces, if the temperature of the air is high, 16° C. or more, they rapidly develop, cast their skins and become sexually mature.

The free-living forms, male and female, copulate, and each female passes thirty to forty eggs from which larvæ are hatched. The larvæ at first are rhabditiform with the double dilatation of the œsophagus, but later this is lost. The œsophagus is then simple, and the larvæ are filariform. They increase in size and when 0·55 mm. in length moult and acquire the characters of their grandparents—the parasitic form. The duration of life in this stage is about eight days, and the larvæ of the human species are incapable of reproduction a second time as free-living forms, and die out unless they are introduced into the human intestine, when they again become parasitic like their grandparents.

When these embryos were first discovered they were

believed to be the cause of intestinal diseases, and particularly of a form of diarrhœa known as Cochin China diarrhœa. It is now known that they may be present in numbers in persons in perfect health, and passing normal motions. In such persons, if diarrhœa be artificially induced, as by purgatives, the numbers of embryos passed will be much increased.

They are more frequently found in persons with diarrhœa, and although they cannot be considered as the cause of the disease, apparently abnormal intestinal conditions are favourable to their multiplication, or that they render the intestine more liable to catarrhal or other conditions, and so indirectly lead to intestinal trouble.

Strongyloides intestinalis is a common human parasite, and widely distributed all through the Tropics. The larvæ are small, but can be readily found on microscopic examination of the excreta, whether these are loose or formed. As a *direct* cause of disease, it is probably unimportant.

CHAPTER IX.

FILARIIDÆ.

THE *Filariidæ*[1] present the simplest structure of any nemathelminths, and those parasitic in man are, therefore, considered before the other nematodes. In most cases they have a complete intestinal canal. The mouth is terminal and unarmed, though in some species papillæ are found near it. The œsophagus is moderately muscular, presents no dilatations, and passes into an alimentary canal of practically the same calibre. The anus is sub-terminal in both sexes.

The opening of the female genital organs, the genital pore, is near the head and sometimes close to the mouth. From the genital pore a short muscular vagina leads into a dilated thinner-walled portion, and into this the two uterine tubes open. These tubes run directly backwards parallel to each other and end in the solid ovaries, which are somewhat convoluted and form loops towards the caudal extremity.

In the male the testis (single, as in all the Nematoda) commences towards the head end as a loop, and the vas deferens runs directly backwards to open at the cloaca. From the cloaca are extruded two unequal spicules, of which the larger is anterior and often appears to be tubular. These spicules can be protruded or retracted independently of each other. Sensory papillæ occur in pairs before and behind the cloaca, but may be so small as to easily escape observation. There are one or two post-anal pairs, and three pre-anal. The males are smaller, often

[1] Termed *Filaridæ* by some authors.

very much smaller, than the females, and the posterior extremity is usually much coiled. Most of the Filariidæ are viviparous. Development of the larva, where it is known, takes place in an intermediate host—an arthropod—to a certain but limited extent. Sexual maturity and full growth is only attained when the larva is again introduced into the warm-blooded host.

Several filariæ are found in man; they inhabit the lymphatics or cellular tissues. In some the embryos find their way into the blood and circulate with that fluid. For diagnostic purposes the larval characters are of greater importance than the adult, as the latter can usually only be found after the death of the host, whilst the embryos are easily found in the blood during life.

Filaria bancrofti.

Filaria bancrofti inhabits the lymphatics or lymphatic glands in various parts of the body, but has more commonly been found in the lymphatics in connection with the pelvis or extremities than elsewhere. The female is 80 to 90 mm. in length, and at its broadest part 0·23 mm. in breadth. The vaginal opening is 0·66 to 0·75 mm. from the head and the anal 0·22 mm. from the tip of the tail. The tail end is pointed. There are no cuticular thickenings or markings on this worm, but there are six pairs of minute papillæ on the head (fig. 40). The junction of the œsophagus and midgut is difficult to make out. The male, 44 mm. in length and 0·1 mm. in breadth, has a blunted tail. Sensory papillæ are very minute, but, according to Leiper, the nerves going to them can be seen, and the papillæ are numerous anterior to the cloaca (fig. 40). The anterior spicule commences in the body as a pitted, trumpet-shaped, chitinous expansion and may be protruded for a considerable distance. The posterior spicule is broader, flatter, and short.

These filariæ may be found in clumps in the lymphatics, and the embryos passed into the lymph are naturally

carried by the thoracic duct into the venous system unless there is lymphatic obstruction.

In most cases these worms do not affect the general health, though as they give rise to a certain degree of eosinophilia they must exercise some toxic effect.

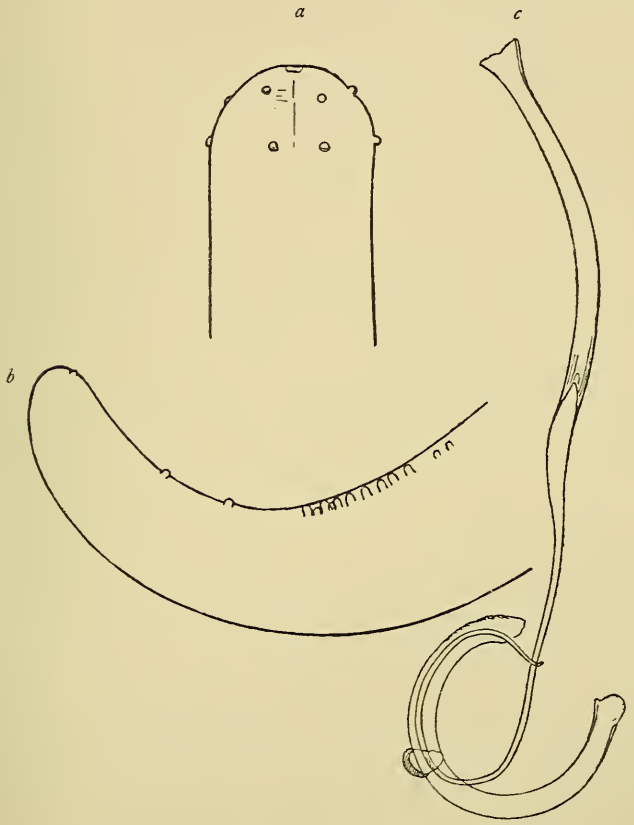


FIG. 40. — *Filaria bancrofti*. *a*, Papillæ on the cephalic extremity in the female ; *b*, numerous minute papillæ anterior to the cloaca in the male ; *c*, spicules in the male. (After R. T. Leiper.)

The disorders attributed to the worm are those due to lymphatic dilatation, obstruction, or inflammation, or to the obliterative changes set up in the glands. These are

probably due to the adult worm. The embryos cause no symptoms as far as is known.

The lymphatics are always dilated where the worms are found, and the commonest lesion to be observed clinically is enlargement of the glands in certain parts of the body, with or without other affections of the lymphatic system.

In the dilated lymphatics hæmorrhage sometimes occurs, so that the whole mass of dilated lymphatics is tense and distended with blood, which coagulates and forms a thrombus. In a portion of such a thrombus—in the groin—more than a dozen living filariæ have been found.

As the thrombus becomes organized it is converted into a fibrous mass and completely blocks up the lymphatics. The included filariæ probably disappear ultimately in the fibrous mass or become calcified.

Occasionally, without any hæmorrhage, suppuration occurs in the dilated lymphatics with the formation of an abscess. Whether this is preceded by the death of the worm is not known. In the abscesses dead worms only have been found.

In other cases there is inflammation which has not gone on to suppuration, and in some instances when the inflamed mass has been excised filariæ have been found. Calcified filariæ have been found by Wise in several regions of the body, and by Bahr in enlarged lymphatic glands.

These accidents are only diagnosable when the lymphatics in which they occur are superficial, but in chronic cases fibrous masses, probably the remnants of such changes, are found in the pelvis or even in the thoracic duct at a *post-mortem* examination.

The glands enlarged may be in one or both groins or in the inguinal canals. These glands are hard and not tender on pressure. Sometimes associated with these enlarged glands is a certain amount of diffuse swelling in the neighbourhood, and comparatively rarely definite

tumours which may be mistaken for hernia, as there is definite impulse on coughing.

When the patient lies down, such tumours diminish slowly in size, but rarely disappear. The tumours may be slightly painful, and often a dragging sensation is complained of. They are formed by dilated lymphatics, and sometimes the sinuous dilated vessels can be in part felt under the skin. The swelling can be followed up the inguinal or femoral canal as the lymphatics pass through these apertures.

Frequently a second diffuse swelling on the inner aspect of the thigh is also present; it is usually situated about the lower half of Scarpa's triangle. The swelling is really part of the upper swelling, but as the fascia is less dense in the lower part of Scarpa's triangle, it appears as a separate swelling. On puncture of these swellings with a hypodermic needle, a clear or more or less milky fluid is obtained. The cells in this fluid are lymphocytes, and a few red corpuscles may be present. In some cases filarial embryos and occasionally eggs with the coiled-up embryo will be found abundantly in the fluid, but in old-standing cases none will be seen.

Bahr has shown that common glands, to be enlarged and to contain living or calcified filaria, are the epitrochlear, antecubital or Crookshank's gland in front of the elbow. Newham and Wise subsequently found living filariæ in these glands in British Guiana. Frequently when living filariæ are found in these glands there are no embryos in the blood. It is interesting to recall that Egan, in 1892, called attention to the frequency with which enlargement or inflammation of Crookshank's gland was found in British Guiana, but the relationship to filarial infection was not then recognized.

When hæmorrhages take place into a mass of dilated lymphatics a tumour of considerable size is formed, even if the swelling were previously small. Such a swelling is of sudden onset, may be, if in the groin or inguinal canals, accompanied with severe pain and, frequently

vomiting. The tumour will feel hard, tense, and tender, and if the blood is coagulated there will be no impulse on coughing. Such a tumour is almost certain to be mistaken for a strangulated hernia, especially as the patient may be constipated.

A condition sometimes met with is pain along the cord in the testicle, or in the back, accompanied with fever and frequently vomiting. The fever may be continuous, but more often there are well-marked rigors and short pyrexial attacks not unlike malaria ("Barbados fever"). The febrile paroxysms may occur, like those of malaria, at any time of the day or night. Sometimes during these attacks the testicle is decidedly swollen and very tender. According to Wise these attacks are in some cases due to the presence of adult filariæ in the lymphatics of the cord.

Associated with similar symptoms there may be acute œdema of the scrotum, and from the surface there may be a profuse watery discharge, sometimes milky—lymph scrotum. In the fluid filarial embryos may be found. In these cases the worms will be higher up than when in the spermatic cord, so that the lymph circulation in the skin is interfered with.

Deep-seated abscess, in connective tissue, may possibly be due to these worms. Such abscesses may be situated under the scapula, under the deep fascia, in any of the limbs, or in the pelvis. No external cause can be found, and they are not connected with suppurating glands, or with disease of the bone. Wise has found adult filariæ in small abscesses in the epididymis and in the cord, and relates a case in which an adult worm was found in the lymphatics in the abdomen, and the right psoas muscle infiltrated with blood containing the embryos, and points out that such a condition could readily lead to the formation of a psoas abscess. He also observed that in a considerable proportion of the cases in which the worms were found death was due to septicæmia. In his observations many adults have been found, and he shows that

most commonly these worms when dead calcify. In a considerable proportion of the cases the worms were in the connective tissue in the hilum of the kidney.

It is not improbable that further investigation will prove that in addition to the obvious and striking manifestations of filariasis, a much graver condition may be present, and owing to the disorganization of the lymphatic system (whether there is obstruction or merely dilatation of the lymphatic vessels), one of the main lines of defence against invasion of tissue and multiplication of micro-organisms in the blood is impaired. Possibly also the stagnating lymph has lost its bactericidal powers. Observations on the bactericidal powers of healthy lymph and of those of the lymph in these dilated lymphatics are required.

Chyluria.—A rather striking manifestation of the disease is chyluria, or hæmatochyluria. In this condition the urine is milky-white in colour, sometimes tinged with pink, and sometimes containing blood-clots or mixed with blood. Rarely the blood is so abundant that the urine is red in colour and looks like blood.

The urine in these cases varies from time to time; there may be long intervals when the urine is normal. Frequently, even during the period when the urine is abnormal, it will be normal when the patient is at rest in bed, so that the first urine passed in the morning may be quite clear, that passed when he has been up slightly milky, becoming more milky or perhaps tinged with blood later in the day. Such a patient, after violent exertion, will often show a marked increase in the amount of blood passed.

Filarial embryos may be found in the chylous urine at any time of the day or night. Frequently the embryos are more abundant in the blood-clot, and they are also often found adherent to any threads that may be present in the urine.

The urine, when allowed to stand, coagulates, sometimes forming a jelly-like mass; in other cases, where there is less chyle, coagulation is partial, so that shreds

of coagulum only are formed. Shaken up with ether the urine becomes clearer as the fat globules are dissolved, but some turbidity always remains. When examined microscopically finely divided oil globules are found throughout the urine in many cases, and blood corpuscles if blood is abundant.

Some authorities dispute the presence of actual blood, and point out that chyle in the lymph-vessels is often pinkish, and that this tinge is often deeper when the lymph has been prevented from escaping from the lymphatics. This change may be the cause of the pink tinge of some chylous urine, but does not account for the coagula of blood, indistinguishable from ordinary blood, in other cases of chyluria.

Chyluria indicates rupture of dilated lymphatics in some part of the urinary tract and obstruction of the thoracic duct.

Chylous ascites is rare, but does occur in filariasis. In this case rupture of the lymphatics into the peritoneal cavity takes place.

Hydrocele is so common an infection in the Tropics that one is tempted to consider that filariasis may be to a large extent responsible for the frequent occurrence of this condition. In a few cases it is so, as the fluid is chylous and contains filarial embryos, and in others, even when the fluid is not chylous, filarial embryos are present. Calcified adult filaria may be found in the wall of the hydrocele. Sometimes the hydrocele is associated with other evidence of lymphatic obstruction. A certain proportion of the cases of hydrocele may be referred to this cause, but it is probably a small proportion only.

In such manifestations as lymphatic varix, chyluria, hæmatochyluria, and lymph scrotum, the association with filarial infection is undoubted, and with a proportion of the cases of enlarged glands and hydrocele it is equally so.

The local chronic swellings of limbs, scrotum, breast, and patches of skin known as elephantiasis are clearly

due to lymphatic obstruction, but in some cases even of marked elephantiasis the obstruction is not due to filaria.

As a very rare disease it may be seen in England, or in other countries where *Filaria bancrofti* is unknown. In the Tropics a similar chronic œdema may result from long standing ulceration as is sometimes seen in the legs, or from new growth as in many cases of granuloma pudendi, or from repeated attacks of chronic erysipelas, and in these cases the swelling may be very marked, as much so as in a moderate case of elephantiasis. In these diseases lymphatic obstruction is produced by inflammation or by other disease, as in lymphodermia. Anything that could cause lymphatic obstruction would lead to similar result.

In the Tropics elephantiasis is not a rare disease, but an extremely common one, and an explanation is required for the frequency with which this manifestation of lymphatic obstruction takes place there, and the frequent existence of a worm in the lymphatics or lymphatic glands affords a plausible explanation. The main arguments for considering this to be due to filariæ are those based on geographical, topographical and racial distribution of this filariasis, as these to a considerable extent correspond with the frequency of diseases due to lymphatic obstruction.

In all countries where filariasis is common elephantiasis is also common, and the variations in both are to some extent proportionate.

In the Pacific Islands and in the West Indies embryo *F. bancrofti* (*F. nocturna*), or *F. philippinensis* are found in 20 to 30 per cent. of the population, and elephantiasis in 1 to 2 per cent.

In the Malay Peninsula, where filariæ are not found in the aboriginals, elephantiasis is unknown amongst them.

In any country, the districts from which cases of elephantiasis come are those in which filariæ are frequently found in the blood of the patients.

Thus in Central Africa elephantiasis is common on the Zambesi and Lower Shiré rivers, and the north end of Lake Nyassa, and in these districts filariæ are found in

a considerable proportion of the inhabitants. On the Upper Shiré River and the south end of Lake Nyassa, as well as on the plateaux, elephantiasis amongst the indigenous inhabitants is unknown, and filariæ are extremely rare.

In British Guiana these embryos are very frequently found in the blood of persons living on the coast, but are not found in persons living in the interior, and no cases of elephantiasis come from the interior.

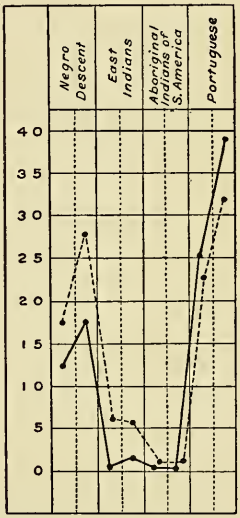


FIG. 41.—Showing the incidence of filaria and elephantiasis in different races in British Guiana. ——— Percentage with elephantiasis. - - - - - - Percentage with filaria.

In a community formed by the association of persons of several races, and living under the same meteorological conditions, it will often be found that the incidence of elephantiasis varies in these different races, and when this occurs there is the same variation in the prevalence of filariasis. For example, in the towns of British Guiana there are Portuguese, Negroes and Indians, and the proportion in the males of each race with filariæ was 30 : 18 : 4.

The proportion with signs of lymphatic obstruction were : Portuguese, 13 ; Negro, 7·4 ; Indian, 0·9.

Even as regards the two sexes the same held good. In British Guiana, amongst the Negroes, 24 per cent. of the females harbour filariæ and 13 per cent. of the men. Elephantiasis occurs in the females 15 per cent., as against 7·4 per cent. in the males (*vide* chart, fig. 41).

The opposition to the view that the *F. bancrofti* is responsible for the prevalence of elephantiasis—lymphatic obstruction—is due to the fact that in the majority of cases of elephantiasis no filarial embryos are found in the blood. This was noted nearly thirty years ago and has been confirmed repeatedly. It is certain that in any country where filariæ are common the proportion of persons harbouring these parasites is smaller in those with elephantiasis than amongst those perfectly healthy.

In some cases, though the filarial embryos are not found in the blood they may be found in the lymph from the elephantoid part, but these cases are rare. In other cases, though no filariæ are present in the blood, there may be a history of previous undoubted filarial manifestations such as chyluria or lymph scrotum. Bahr, and others subsequently, have shown that there may be sexually mature living filariæ in the glands and none of the embryos have passed into the blood.

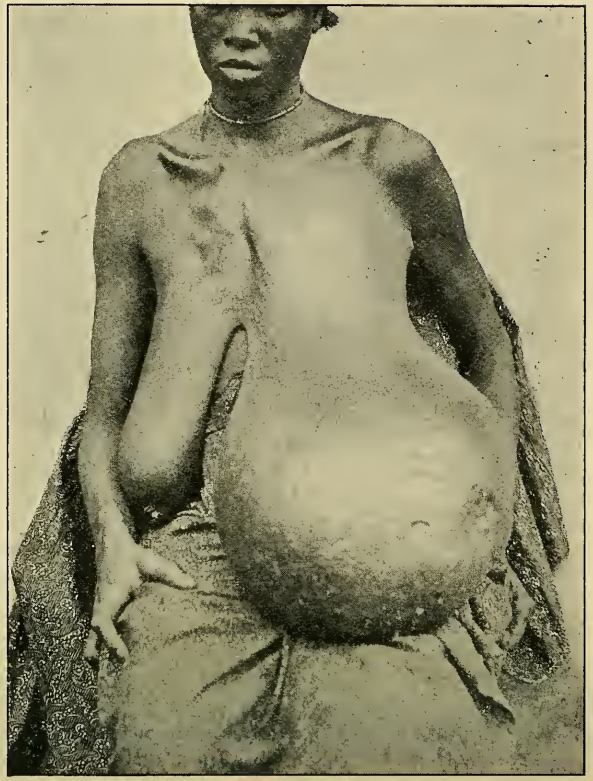
Those who support the proposition that *F. bancrofti* is responsible for the prevalence of elephantiasis—lymphatic obstruction—urge that the absence of filaria from the blood in these old-standing cases of lymph obstruction might be expected.

The adult causes the obstruction, but in so doing shuts off the lymph in a given area from the general circulation and the embryos therefore cannot get into the blood. Further, the obstruction once formed is persistent, whilst the filaria that caused the obstruction will die, and it is even suggested that the obstruction is caused in many instances by dying or dead filariæ.

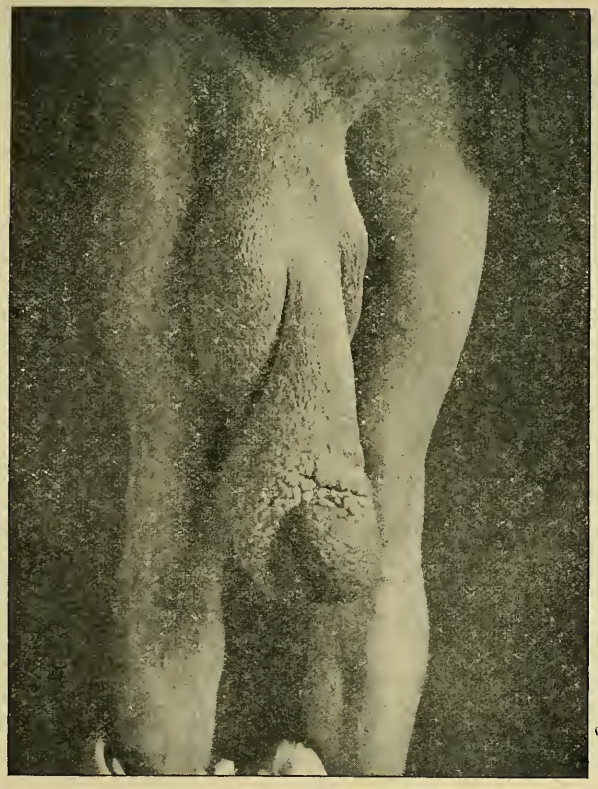
Before considering these views it is well to take into account the clinical history of cases of elephantiasis.

FIG. 42.—ELEPHANTIASIS.

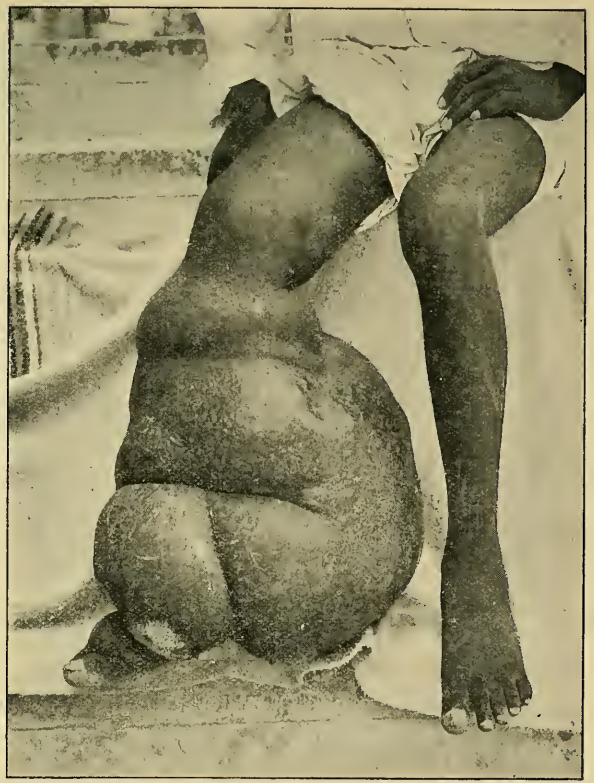
(1). Scrotum.



(2) Breast. West Coast of Africa.



(3) Penis. European some years after leaving Egypt, from photo by Dr. Hunt.



(4) Leg. India.

The established elephantoid condition is far more common in the legs than in any other part of the body. One leg alone may be involved or both legs to an equal or unequal extent. Sometimes the condition is limited to the part below the knee, more commonly there is also thickening of the thigh. Where boots are worn regularly the swelling of the foot may be less than that of the legs.

Next in frequency is elephantiasis of the external genitalia. In the male both scrotum and penis are usually affected, but cases occur of the penis only, and sometimes of the scrotum only (fig. 42). In the female the labia majora are the parts affected. Elephantiasis of the upper extremities is rarer, but is commoner in the natives of the Pacific Islands than in other places.

The breast, either one or both, may be elephantoid, and localized patches of skin, usually in the groin, but occasionally in other parts of the body, are sometimes found, with or without elephantiasis of the legs. The swelling in the part attacked may be enormous. The scrotal tumour may weigh over 100 lb., and tumours weighing 40 or 50 lb. are common. Even the localized groin tumours may weigh from 10 to 20 lb. On section of an elephantoid tumour there is a free discharge of watery fluid, usually clear, and it will be seen that the tumour is formed entirely by the subcutaneous tissues. The muscles are not enlarged, and the intermuscular fibrous tissues appear normal.

The thickness of the subcutaneous tissue is greatly increased and usually there is abundant fat. The skin is frequently thickened and presents a pitted appearance, as the effusion is between the strands of the subcutaneous fibrous tissue, and these are still effective in binding the skin down.

Owing to the deep folds formed near a joint, it is difficult to keep the skin clean, and epithelial *débris*, sweat and dirt collect in these folds, and ulceration and eczema are common.

The vitality of the skin is not high, ulcers readily form and heal with difficulty; more rarely gangrene occurs.

The onset of elephantiasis varies. In some cases it may be gradual, without pain, fever, or any local inflammation. The patient notices that the limb begins to swell and that this swelling continues. In many of these cases after a time attacks of lymphangitis occur. More commonly there is a sudden onset, with fever, often rigors, and the limb becomes swollen, painful and hot, and is red and obviously inflamed. Such an attack resembles erysipelas, and is known in the West Indies by the old English name for that disease, "rose." It is not often fatal, but abscesses may occur, and red lines in the course of the lymphatics above the swollen part may be seen, and the glands, whether previously enlarged or not, become swollen and tender. The acute symptoms pass off, and the swelling subsides to some extent but not completely, and after a time the painless chronic œdema supervenes and steadily increases.

Frequently there is a series of such erysipelatoid attacks at intervals of weeks or months, and each attack leaves the limb larger than it was before, and even in the intervals increase in size takes place. These erysipelatoid attacks usually commence without any warning or any local skin lesion or injury; but they are more frequent in the wet weather and after heavy rains. Most of the persons attacked go about bare-footed, so that they are exposed more to the risk of injuries which may escape notice. Thrombosis of the veins occasionally occurs.

Any hypothesis which can be regarded as affording a satisfactory explanation of the causation of elephantiasis must explain: (1) The distribution of the œdema, which does not always correspond with a blockage of main lymphatic vessels; (2) a gradual onset without acute inflammatory symptoms; (3) the onset with an acute inflammatory attack or recurrent inflammatory attacks; (4) the absence of filarial embryos from the blood and usually from the lymph of the affected part.

The known ways in which lymphatic obstruction is produced by filariæ, namely, by causing hæmorrhage or

by leading to inflammation or suppuration, events that seem sometimes to be associated with the death of the worm, would not explain those cases in which the onset is gradual, nor the steady increase in the lymphatic œdema following a single attack of "rose." They might explain some of the cases, especially those associated with obstruction of the main lymphatic trunks or in the glands. In some cases where these events have been known to occur in accessible portions of the body no elephantiasis has followed. These methods would account for the absence of filarial embryos, as the adult worms in the region of the block are either dead or are enclosed in an organized blood-clot, or in inflammatory exudation. In any case the embryos discharged into the lymph behind the obstruction would not be able to get into the blood-stream.

The main lymphatic systems are normally separated from each other, though there is free anastomosis of the lymphatic channels at the periphery of the system. This renders it improbable that a single local obstruction should cause such extensive progressive œdema. In chronic diseases, as in carcinoma, we know that a collateral lymph circulation may be established. Enlarged hard glands are so commonly present in cases of elephantiasis above the affected area that it is probable that much, if not the main part, of the obstruction takes place in them.

In the scrotum where the lymph escapes through several channels no single obstruction could produce the results so commonly seen. Multiple obstructions involving a number of small lymphatic vessels would be necessary to cause sufficient obstruction. Such gross obstructions as those directly due to the living or dead adult filariæ would therefore explain only some of the phenomena.

Manson has suggested a hypothesis which at first sight seems far-fetched, but on closer inquiry appears to provide a fairly complete explanation of the observed

phenomena. This hypothesis is based upon actual observations. The adult *Filaria bancrofti* passes living embryos completely stretched out but still enclosed in the egg-capsule which forms the loose sheath. The outlet to the vagina of the female is a narrow muscular tube which is just large enough to allow the exit of these embryos one by one. These embryos, 7·5 μ in diameter, are passed into the lymph in which the adult worm lies. The lymphatic vessels anastomose freely, and frequently the larger ones inosculate.

Before reaching the main lymphatic trunk the lymphatics at least once subdivide into minute capillary lymph channels in the lymphatic glands. The lymph from the skin passes first through fair-sized lymphatics and then through these capillary tubes, which are of just sufficient size to allow of the passage of filarial embryos, and consequently no obstruction takes place in these lymphatic glands.

Occasionally, however, instead of stretched-out embryos, ova with the embryos coiled up in them are passed. These eggs have been seen by several observers in the dilated lymphatics in which the parent worms lie. Such eggs can only be passed if the adult aborts. This abortion may be from defect or injury to the adult worm. These eggs are up to 20 μ in diameter and are too large to pass through the smaller lymph-channels or through the lymphatic glands.

An adult filaria situated in the lymphatics or on the peripheral side of such glands would, if it aborted, pass these eggs, and they would be carried with the lymph-stream into the glands and block the lymphatic channels in these and in the finer lymphatics. If eggs were still passed they would now be carried by anastomosing vessels and block up the finer vessels, and the glands in this collateral circulation also. Provided the eggs continued to be passed, in turn all collateral circulation of lymph would be blocked, and there would be complete lymph stasis in the skin and subcutaneous tissues which were drained

by the lymphatic vessel in which the worm was situated. We know that worms are found in the lymphatics on the peripheral side of the glands. We know that eggs too large to pass through glands are sometimes passed by *F. bancrofti*. The results, on account of the peculiarities of the division of lymphatic vessels, are such as might be expected, and therefore the hypothesis is a logical one. Bahr, and subsequently others, have shown that living worms may be present in the glands, but the embryos do not find their way into the circulation. A worm in the gland tissues may cause hæmorrhage, and always causes fibrosis and round-celled infiltration of the glands, leading to their functional destruction and conversion into fibrous masses. Numerous eosinophile leucocytes may be found in the exudate.

The frequency of enlarged hard glands in association with elephantiasis, the varying onset, gradual and without acute symptoms, presumably when the discharge of ova is slow and gradual, and with acute symptoms when more rapid, and possibly aided by acute lymphangitis of bacterial origin, affords a plausible explanation of the elephantoid condition. The absence of embryos from the blood would be the result of the blockage of the lymphatics in which the adult lived, or is still living. Their presence in the lymph of the affected part would continue as long as the worm was alive, but as the cases of elephantiasis by the time they are examined are usually of many years' standing, the worms would probably have died. Reinfection, which is the rule when the embryos are in the blood, would not occur when they were shut off from the blood and only found in the lymphatics.

Treatment.—Elephantoid tissue is difficult to keep clean, and, as already mentioned, ulcers are apt to occur in the deep folds. The tissue is of low vitality, and chronic ulceration is common. Any injury or laceration heals slowly. Sloughing and gangrene are not unusual. Cleanliness, and care to avoid minor injuries, and rest when any acute symptoms supervene, will prevent these

serious troubles. Careful bandaging, massage, and the use of high-laced boots will do much to prevent the increase in the elephantoid condition. Enlarged glands, if superficial, should be excised. The worms may possibly be removed, and in any case the glands are so changed as to be useless.

Tumours of the scrotum and vulva, if of large size, lead to much inconvenience, and the removal of the tumours is advisable. The operation consists essentially in the removal of a large mass of skin and subcutaneous tissue. In the operation on the scrotum, the penis, spermatic cords, and testicles must first be isolated and protected from injury, and then the bulk of the tumours can be removed.

The risks of the operation are septicæmia and hæmorrhage. It is difficult to get the irregular mass of skin aseptic, but every endeavour should be made to do so. Hæmorrhage is variable. There are usually no large vessels, but there may be an enormous number of small ones. These vessels do not contract readily when divided and therefore should be tied.

In the actual operation it will often be found that the skin at the base of the tumour is healthy, but it is dragged down from the abdomen by the weight of the tumour. It is well to mark the line of the proposed incision as a preliminary. If this is not done the effect of a tourniquet will be to make it difficult to see the exact line.

In order to diminish the loss of blood it is better to place a tourniquet round the base of the tumour before isolating the testicles and penis. The bleeding during this process is then easily controlled.

If a catheter can be passed it is well to do so at once, but it is usually necessary to slit up the elephantoid tissue to find the meatus. When this is found the catheter should be passed and the incision extended through the skin, so as to expose the penis up to the symphysis pubis. An oblique incision should then be made on each side

in order to expose the cords and testicles, which are then dissected out. If a hydrocele is present the tunica vaginalis may be excised. The possibility of a hernia must be carefully kept in mind, and this possibility finally excluded by examination of the abdominal rings through the incision. Any vessels are secured and the tourniquet relaxed and removed and the bleeding stopped.

The penis and testicles, wrapped in warm sterilized towels, must be secured on the anterior wall of the abdomen, and a tourniquet applied tightly round the base of the tumour. When the tumour is removed this would almost certainly slip unless secured. The simplest method is to transfix the healthy skin at the base of the tumour with two long skewers at right angles to each other, and apply the tourniquet above them. The tumour can then be removed, boldly following the lines already mapped out. All vessels that can be seen should be tied, and the tourniquet gradually relaxed, and other bleeding points as they appear secured. The testicles should be covered with any available skin, and the penis should be covered as much as possible. In some cases the skin round the glands, though inverted, is quite healthy and should be retained.

One assistant at least in addition to the anæsthetist is advisable in this operation.

Results are very good, but the penis is frequently bound down by cicatricial tissue. The testicles usually appear to be distorted and atrophied, but in some cases are less so in reality than they appear to be, as after the operation connection and procreation are possible.

Pendulous tumours can be removed in a similar manner. In any tumours of the scrotum, about the groin, and even the vulva, the possibility of hernia as a complication must be remembered.

Elephantiasis of the limbs in the early stages can be checked by the use of elastic bandages and by massage. In more advanced cases the question of operation may arise. In many persons the limb, though enormously swollen, is quite useful and no operation is necessary.

The operations on the limbs when the bulk is excessive are not very satisfactory. Ligature of the femoral artery was at one time practised, but was very liable to be followed by gangrene, and the results were most unsatisfactory. It is no longer practised.

Removal of longitudinal wedges of skin and subcutaneous tissue is fairly satisfactory as regards appearance, and the drain of lymph from the incised surfaces aids in the diminution of the bulk. As regards utility there is as a rule no benefit. Castellani advocates the combination of this method with the use of fibrolysin, but it is too early to form any opinion as to the final results of his operation.

In the opinion of the author most of these operations are, as regards *final* results, disappointing.

Attempts at producing an anastomosis between the dilated lymphatics and a large vein have not been successful.

The establishment of passages in the subcutaneous tissue by the insertion of long silk ligatures, so that drainage may take place from one lymphatic system into another, is more promising, but so far little or no *permanent* advantage has resulted.

Tumours formed by varicose lymphatics are best left alone. Death has in several instances followed their removal or incision, as an acute general sepsis has resulted. No such results have followed excision of the enlarged antecubital glands.

Treatment of the complications of filariasis due to *Filaria bancrofti* must be conducted on general principles. There is no specific treatment of the condition itself. The worms cannot be killed, and it would be of doubtful value to do so. It has been noticed that in the course of treatment (of trypanosomiasis) of persons with filariæ by injections of atoxyl or tartar emetic the embryos have disappeared permanently from the blood without any bad effects. Further observations show that the effect is on the embryos only, and there is no advantage in destroying these as the adults are unaffected.

The worms are often numerous, and unless they cause hæmorrhage or suppuration cannot be located. The lymphatic obstruction has been produced by the time the patient comes for advice.

In chyluria violent exertion must be avoided, and if blood appears absolute rest insisted on.

A person known to be suffering from filariasis should live in a country where auto-infection is impossible. Such a country must be one in which *Culex fatigans* does not occur or is not numerous, otherwise he will infect the mosquitoes that feed on him, and they in turn will re-infect him, so that the number of adult filariæ will be increased continuously.

If circumstances do not permit of a patient living in a country with so temperate a climate, he must be warned as to the necessity of guarding himself against mosquitoes, and of killing such mosquitoes as feed on him, both for his own sake and that of others living in the house.

Diagnosis.—Filariasis is diagnosed by finding the embryos in the peripheral blood, but in some cases even when the adult filariæ are in the lymphatic glands and alive, no embryos are present in the blood. Eosinophilia of a moderate degree and enlarged glands may be of some value. In the infections with *F. bancrofti* the blood must be examined at night, as the embryos are most numerous at night and in many cases are not found in the daytime. The films should be made as thick as possible, and the blood can either be examined fresh or the thick films when dry can be dehæmoglobinized by placing them in water. In most countries the blood must be taken at night, but in the Philippines, Fiji, and other Pacific Islands the embryos are as numerous by day as by night. The worms, which have no definite periodicity, are called *F. philippinense*, but Leiper has shown that the adults are indistinguishable from *F. bancrofti*.

The clinical manifestations, if any, are those of lymphatic obstruction. In chyluria, lymph scrotum, and in many cases of lymph varix the embryos of the

filaria are found in the peripheral blood taken during the night. There is a varying degree of eosinophilia, usually moderate.

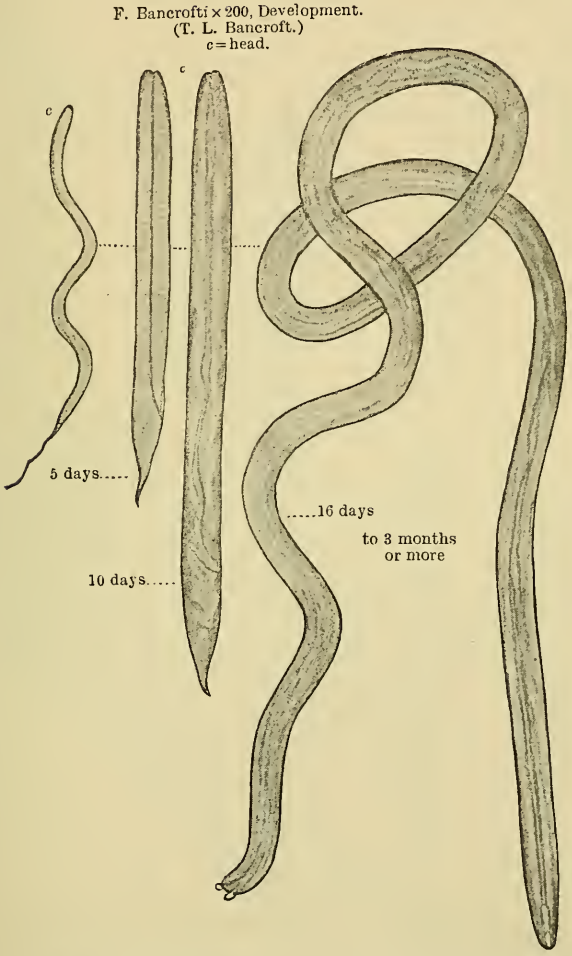


FIG. 43.—Stages in development of larva of *Filaria bancrofti* in mosquito.

The differential diagnosis on morphological characters of filarial embryos found in the blood will be considered later in detail.

In elephantiasis, unless the patient comes from, or has been living in, a district where filariasis occurs the condition cannot possibly be attributed to *F. bancrofti.* Such cases occur in England, but are rare. If he has resided

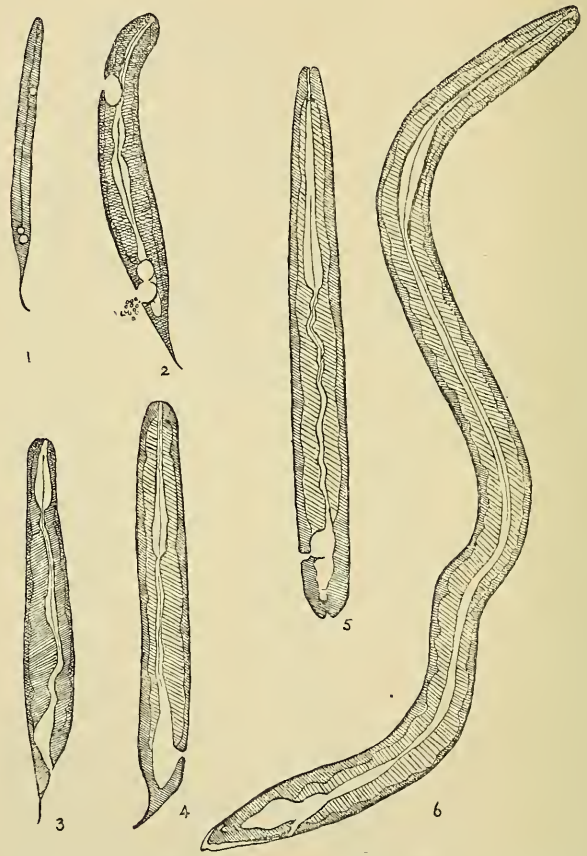


FIG. 44.—Development of intestine in larvæ. (P. H. Bahr.)

in a district where filaria occurs, the elephantiasis is probably due to a filarial infection, past or present, even if no embryo can be found in the blood.

Etiology.—The method of the introduction of the filaria

into man is now well known. It is transmitted from man to man by mosquitoes of many species belonging to several genera. The mosquito takes up filarial embryos

FIG. 45.—Filariæ in thorax and travelling forward into proboscis on the tenth day of development in *Stegomyia pseudoscutellaris*. Camera lucida. (P. H. Bahr.)

with the blood. These, in the case of *F. bancrofti*, are enclosed in a sheath—the stretched-out egg-capsule. In the stomach of the mosquito the embryo casts this

sheath—ecdysis—and becomes an actively locomoting larva. This larva penetrates the stomach wall of the mosquito and travels to the muscular masses, usually those in the thorax. When the larvæ reach this shelter they lie parallel to the muscular fibres and cease to be actively motile, but are not encysted (fig 45). The larvæ swell up and become much broader; usually a small portion of the posterior extremity remains as a sharp-pointed tail (figs. 43 and 44). They steadily increase in size, and develop an intestinal canal, and again become motile and pass into the head of the mosquito. The limit of growth in the mosquito may be reached in a warm climate in ten days. In cold weather and in some species

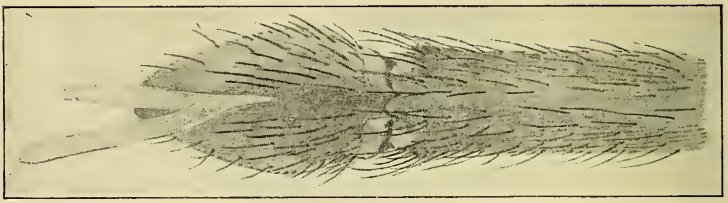


FIG. 46.—The proboscis of an infected mosquito compressed, showing the filarial larvæ extruded through Dutton's membrane. (From a specimen of Bancroft, jun.)

of mosquitoes this period is much prolonged. When the full development of the larva is attained, it continues to live for months, as long as the mosquito remains alive, though no further growth takes place.

The mature, actively motile larva travels to the anterior part of the thorax or head (fig. 45), and finds its way into the inferior lip or labium of the mosquito, sometimes into other appendages. This part of the mouth does not penetrate through the skin when the mosquito feeds, but the embryos probably burst through the weak point in the proboscis—the membrane, Dutton's membrane, stretching between the two labellæ (fig. 46). They do not enter at the wound, but when they have escaped from the

proboscis penetrate the skin, possibly through the ducts of the sweat glands. The mature larvæ are thus again introduced into man. The further stages in the development of the sexless larvæ to the sexual adults have not yet been traced.

It will be seen, therefore, that given suitable mosquitoes which will live for ten to fourteen days after biting a person with filaria, these can in turn either reinfect the same person or infect other people.

The number of species of mosquitoes which can carry filaria is very large, but the full stage of development has been shown not to occur in all. Several of the Anophelina can convey filaria—*Myzomyia rossii*, *Myzorhynchus sinensis* and *M. barbirostris*, and *Pyretophorus costalis* are the more important examples. Of the Culicines there are several species of Culex, Mansonoides,[1] &c., but *Culex fatigans* and *Mansonoides uniformis* are the main carriers. *Stegomyia fasciata* and *S. scutellaris* are not suitable hosts, as the full development of this filaria will not take place in them. *S. pseudoscutellaris* is an excellent host, and has been shown by Bahr to be the important host in Fiji. It is a day-feeding mosquito, and possibly the absence of periodicity in the embryo may be connected with this.

The dangerous mosquitoes are those that are most thoroughly domesticated, that is, frequent human habitations and remain in or near them. *Culex fatigans* is the most important carrier, but *Mansonoides uniformis* is in some places of equal or greater importance. Occasionally, no doubt, some of the other carriers do convey the disease, but comparatively rarely.

The most important species to be considered as carriers of *Filaria bancrofti* are therefore (1) *Culex fatigans*, (2) *Mansonoides uniformis*, and (3) *Stegomyia pseudoscutellaris*. A knowledge of the life-history of these mosquitoes is

[1] *Panoplites* and *Mansonia* were names previously given, but had been used for other species of animals.

essential for prophylaxis. They differ in their habits greatly.

(1) *Culex fatigans* is found in numbers only in the vicinity of human habitations, and is abundant in even the largest towns provided there is still water, fresh or stagnant, in the vicinity. The eggs are laid in rafts floating on the surface of the water and hatch after about two days. The larvæ are provided with a tapering respiratory siphon of medium length and the larvæ feed mainly on substances floating in the water. The "brushes," or tufts of hairs placed on either side of the mouth, are long and composed of numerous fine hairs.

When food is abundant these larvæ, after casting their skins—ecdysis—four or five times, pupate in from six to nine days, according to the temperature, and the pupa now enclosed in a pupal case requires no further feeding. There is no mouth and no anus, and air is supplied through the thorax by the two respiratory tubes. Two days after pupation the pupal case is split down the back and the imago slowly emerges.

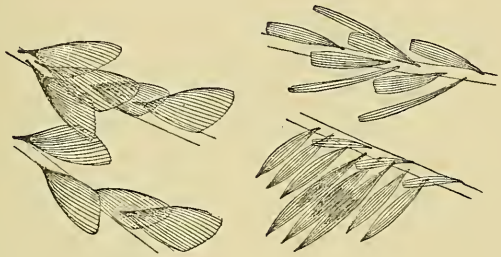
Favourite breeding places are roadside trenches, cesspits, and any small pools where fish are not abundant. They also breed freely in the water of barrels, tanks, and other artificial receptacles. The larvæ are hardy, but will not stand desiccation, and the eggs also, if thoroughly dried or immersed in water, die. The eggs cannot remain unhatched for long; they either hatch out in a few days, dependent on temperature, or they die.

The measures to be adopted consist of limitation of mosquito breeding places, and the destruction of such larvæ as are found. This would seem to be more easy than the destruction of *Stegomyia fasciata*, as the eggs are so much more easily destroyed. In practice this is not so, as the adults—imagines—are stronger and travel further. With the Stegomyia the breeding places are close to the house, and a house can often be freed from such mosquitoes by the destruction of the breeding places in the one compound.

Culex fatigans may be abundant in a house, though no breeding places are near it. The breeding places cover a wider area, and those in the neighbours' compounds must also be destroyed, or even in the whole township.

Private enterprise is therefore less effective. Combined and compulsory efforts, through a central authority, such as a municipal board, are required. This authority must have powers of inspection, and be able to compel action, or to take it themselves at the cost of the occupier of the land in which the breeding places are.

The measures adopted for the extirpation of *C. fatigans* would involve the destruction of some of the other less



Mansonoides. *Culex.*

FIG. 47.—Wing-scales of *Mansonoides* and *Culex*.

important carriers of filaria, such as the *Myzorhynchus sinensis, M. barbirostris*, and *Myzomyia rossii* and also the Fijian carrier, *Stegomyia pseudoscutellaris*. They would have no effect in diminishing what is in some places the important carrier, *Mansonoides uniformis*.

Mansonoides uniformis is readily recognized by the broad asymmetrical scales on the veins of the wings. These scales are in marked contrast with the narrow scales found in most Culicines (fig. 47). The scales on the head are very abundant, and include narrow curved, upright forked, and tile-like scales. There are scales on the basal and second joint of the antennæ. It is a yellow-brown mosquito and the legs are much banded, whilst the

markings on the thorax are less conspicuous. These mosquitoes are found, as a rule, in the vicinity of rivers and lakes and may be very numerous. The mosquitoes do not, like *Culex fatigans*, remain in the houses all day but enter at dark, and bite most viciously for a few hours after dark, leaving the houses before daybreak. *Mansonoides albipes* often enters houses at daybreak, and, therefore, though they can carry the worm, do not have the same chances of acquiring the infection.

FIG. 48. — *Stegomyia pseudoscutellaris* in act of feeding, showing stilettes entering the skin between the labellæ of the buckled-up labium. Drawn from life. (P. H. Bahr.)

These mosquitoes are hardy, and can readily be kept in captivity, but under such circumstances very rarely deposit their eggs.

The larvæ and pupæ are found in the sedges and grasses at the edge of lakes and streams, and the adults are only found in large numbers a comparatively short distance, half a mile or so, from the banks. To clear the sedges

of such streams could only be undertaken where there was a large settlement.

(2) *Mansonoides uniformis* requires for its development and greatest activity a high temperature and a moist atmosphere, just the conditions under which mosquito-proof houses are least popular. Mosquito nets and mosquito-proof houses are the only satisfactory method of preventing the infection where it is absolutely necessary that such a site has to be chosen for a habitation. This mosquito is a dangerous carrier of filariasis in small settlements on the banks of large rivers and lakes.

During the daytime the mosquitoes rest amongst the vegetation, and the vicinity of the house should therefore be kept as clear as possible from long grass and bush.

Fumigation of the inhabited rooms of houses from shortly before to two hours after dusk with burning pyrethrum will very much diminish the number of mosquitoes which enter the houses.

(3) *Stegomyia pseudoscutellaris* (fig. 48) closely resembles *S. scutellaris*, but the thoracic markings are more extensive, especially laterally, and the abdominal bands are incomplete. The larvæ are also similar, but the spines on the penultimate abdominal segment are different. In habits the imago differs, as it is a pure day feeder and the larvæ are found in brackish water near the coast, whilst *S. scutellaris* is a jungle mosquito in the main, and feeds at night even more than in the day. It does not occur in Fiji.

Destruction of larvæ is not easy, as thorough drainage of low-lying land near the coast is difficult. Bahr in closed places had some success with copper sulphate, 1 gr. to 437 gallons, but it is only larvicidal to the freshly hatched larvæ; the more mature larvæ can thrive in the solution if vegetable food is abundant.

CHAPTER X.

OTHER FILARIÆ.

Filaria perstans is a smaller and much weaker worm than *F. bancrofti*. The head is larger but the body is thinner. The tail of the female is slightly curved, and at the tip are two prominent cuticular thickenings. The male has well-marked pre- and post-anal papillæ. This worm is found in Africa and amongst the aboriginal Indians in British Guiana and probably in other parts of South America. It is common in well-wooded places where the temperature is high and the air moist.

The adult forms are found in connective tissue in the vicinity of the alimentary canal, at the root of the mesentery, and occasionally in the posterior mediastinum. They do not appear to give rise to any local trouble.

At one time it was suggested that sleeping sickness might be due to this worm, but since the discovery that that disease is the terminal stage of infection with the *Trypanosoma gambiense* this hypothesis has been abandoned. No symptoms are known to be caused by *F. perstans*. The intermediate host is unknown. Many species of mosquitoes have been proved not to carry the disease. It is so common to find in one village practically everybody infected, and in another near it no one that in all probability the carrier is a common domesticated arthropod that does not travel far and that does not remain infective for long periods or transmit the infection to a second generation. *Ornithodorus moubata* would fulfil these conditions in Africa.

Filaria demarquayi is found in many of the West

Indian Islands. The adult females, only, were found by Galgey in subperitoneal tissue.

The sharp-tailed, sheathless embryos are found in the blood at all times and may be numerous. They are indistinguishable from embryos found in British Guiana, known as *F. ozzardi*. *F. ozzardi* is probably widely distributed amongst the aborigines in Central America.

Female adult forms were found in one case, also in subperitoneal connective tissue, but these are believed by Leiper to be specimens of *F. bancrofti*. If this is correct it will be the first recorded case of *F. bancrofti* in a native of the interior of British Guiana. No embryos of *F. bancrofti* were found in the blood in the course of numerous examinations. The adult forms presented certain differences from those found by Galgey. Till more specimens of the adult forms, including the males, of the West Indian and South American sharp-tailed embryos are found it is better to consider them doubtfully as belonging to distinct species.

Neither *F. ozzardi* nor *F. demarquayi* is known to cause any disease.

Filaria loa (Loa loa).

Filaria loa is widely distributed on the West Coast of Africa, and in some places, as in Nigeria, is a very common parasite, but it does not occur in Asia or America. Europeans are often infected.

The parental forms are strong, active filariæ, and differ in many important respects from the filariæ already described. The cuticle is studded over with small bosses. The worms are comparatively short and broad, and very muscular. Immature forms are often met with.

The Male.—The papillæ, three pairs of pre-anal and one pair of post-anal, are large and prominent, and there is a second small post-anal pair. The spicules are short and unequal (figs. 49 and 50).

The adults live in the connective tissues and the muscles. They move actively, and frequently travel

through the subcutaneous tissue, so close to the surface that they can be easily felt and seen through the cuticle.

Often they pass under the conjunctiva. They may sometimes be transfixed and killed, but are not easy to extract as they move rapidly and dive down into the deeper tissues when an incision is made.

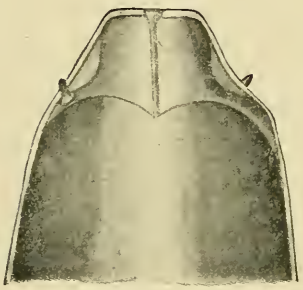


FIG. 49.—*Filaria loa.* The anterior extremity of a male, magnified. (After R. Blanchard.)

FIG. 50.—*Filaria loa.* The posterior end of a male, magnified. (After R. Blanchard.)

Additional smaller papillæ are described by Leiper.

When they move in the deeper parts of the subcutaneous tissue or in the muscles they sometimes cause painful swellings—Calabar swellings. These do not suppurate and usually subside in a few days, though others may appear elsewhere even before the subsidence of the first. In the wrists and forearms these tumours may cause serious inconvenience. The swelling may be considerable and is deep-seated. In some cases the whole limb may be swollen and give rise to a suspicion of elephantiasis. It is easily distinguished as the skin is quite

smooth and does not show the markings and irregularities that occur in elephantiasis. Embryos, if found in these infections, are sheathed and have a diurnal periodicity—*Microfilaria diurna*. Manson suggests that these swellings are caused by the parturition of an adult female at the site of the swelling. So far this has not been proved, but in one case a worm appeared on the surface of such a swelling.

Eosinophilia is marked in infections with this worm. Sometimes the eosinophiles form 70 per cent. of the total leucocytes.

Though the evidence is in favour of the view taken here that *F. loa* is the parental form of *Mf. diurna*, and that Calabar swellings are due to this worm, there are many points that require explanation. In some cases of Calabar swelling no microfilariæ have been found, though repeated examinations, extending over many months, have been made. In other cases where *Mf. diurna* is common no Calabar swellings have occurred. In persons from whom *F. loa* has been extracted the microfilariæ have not always been found, probably because the filariæ were immature.

The embryos are found in the peripheral blood in the daytime, and as a rule not at night. Change of the habits of the host in one case did not cause any change in this periodicity.

The living embryos are indistinguishable, except by their periodicity, from those of *F. bancrofti*, but the stained specimens can be fairly readily distinguished.

A thorough investigation is required as to the causes of the variation in the effects of this worm. Every combination may be found: (1) Cases where Calabar swellings, *F. loa*, or *Mf. diurna*, are found alone without either of the others. (2) Cases in which *F. loa* have been extracted, and there are *Mf. diurna* in the blood, but no Calabar swellings. In some of these cases Calabar swellings ultimately develop. (3) Cases in which *F. loa* have

been extracted and there are Calabar swellings, but no *Mf. diurna* have been found in the blood.

The intermediate host has been proved by Leiper to be a *Chrysops*. Both *C. dimidiata* and *C. silacea* have been proved to be carriers. It is interesting to note that many years ago a specimen of *C. dimidiata* was deposited by Manson in the British Museum with the note that it was called by the natives the "Mangrove

FIG. 51.—*Chrysops dimidiata.*

Fly," and believed by them to be the cause of Calabar swellings. The fact that the embryos are not found in the blood at night renders it improbable that any of the domestic species of mosquitoes are the carriers, though many jungle mosquitoes are preferentially day-feeders and experiments have shown that mosquitoes are not carriers. The embryos, after leaving the stomach, migrate to the salivary glands and there undergo the full development up to the stage where they are sufficiently mature to be introduced into the warm-blooded host.

Prevention.—Protection from the bites of *Chrysops* is all that can be done at present. The life-history of these species of *Chrysops* is unknown, and in all probability, like other *Tabanidæ*, the breeding-places are in shallows at the edge of water, or in wet sand. These larvæ are semi-aquatic, and the eggs are deposited on twigs or leaves in the vicinity of, or floating on, water.

Treatment.—The local conditions, Calabar swellings, are temporary. The worms, when superficial, may be removed, but it is only when they cross the conjunctiva that they are troublesome.

Diagnosis of Filariæ.

Diagnosis of Filariæ.—The adults of these blood filariæ are difficult to find even in a *post-mortem* examination. Such a diagnosis could only be made during the life of the host in the case of those worms found near the skin. In the course of an operation others, such as *F. bancrofti*, may be found, or calcified remnants of them.

The differential diagnosis of the filariæ whose embryos are found in the blood of man is not very difficult, as these embryos can usually be distinguished from each other. The points of value in distinguishing between them are :—

(1) The presence or absence of a loose sheath.

(2) The times during which the embryos are present in the peripheral blood—periodicity.

(3) The character of the termination at the narrow end.

(4) The nuclear core and how it terminates anteriorly.

(5) Dimensions of the embryo when alive and when dried on a slide.

(6) Position assumed by the worm in death.

(1) The presence of a loose sheath is of great importance. Of the embryos found in man, those of *F. bancrofti*, *F. loa*, and *F. philippinensis* (the adult is indistinguishable from *F. bancrofti*) have a sheath. The others have not.

	F. bancrofti		*F. perstans*		*F. ozzardi*
	Female	Male	Female	Male	Female
Length	80–90 mm.	44 mm.	70–80 mm.	45 mm.	81 mm.
Greatest breadth ...	·23 mm.	·1 mm.	·12 mm.	·06 mm.	·21 mm.
Diameter of head ...	·055 ,,	·05 ,,	·07 ,,	·04 ,,	·05 ,,
Character of cephalic end	—	—	—	—	—
Distance of genital pore from head (female)	·66–·75 mm.	—	·6 mm.	—	·71 mm.
Diameter at point of genital pore	·14 mm.	—	·07 ,,	—	·12 ,,
Distance from tail of anus	·225 ,,	—	·145 ,,	—	·23 ,,
Cuticular thickening on tip of tail	None ...	None... ...	Double terminal cuticular thickening	—	None... ...
Spicules (male) ...	—	Two unequal anterior and posterior, both retractile	—	Two unequal spicules	—
Papillæ (caudal) ...	None ...	Numerous but minute	None ...	Four pre-anal and one post-anal. Very close to opening of cloaca	None... ...
Habitat	Lymphatic system		Connective tissue, usually subperitoneal ...		
Geographical distribution	In most tropical regions ...		Africa (West Coast and Central), British Guiana		British Guiana

F. demarquayi		*F. loa*		*F. magalhães*	
Female	Male	Female	Male	Female	Male
65–80 mm.	Not known ...	50–55 mm.	30–35 mm.	155 mm.	83 mm.
·21–·25 mm.	—	·55 mm.	—	·6–·7 mm.	·3–·4 mm.
·1–·09 ,,	—	—	—	·06 ,,	·04 ,,
—	—	—	—	—	—
·76 mm.	—	2·35 mm.	—	2·56 mm.	—
·1 ,,	—	—	—	·58 ,,	—
·25 ,,	—	·3 mm.	1·75 mm.	·13 ,,	—
Cuticular thickening over tip. Knobby and irregular in outline	—	No thickening over tip. Two lateral alæ. Cuticular bosses not found at tip, but over the greater part of the body	Thickening over tip. The "bosses" so abundant over the cuticle in the body of the worm are not found at the tip	None ...	None.
—	—	—	Two unequal, anterior and posterior	—	Two spicules.
—	—	—	Three pre-anal pairs and two post-anal. The last are small. Other smaller papillæ are described by Leiper	—	Four pre-anal and four post-anal
Subperitoneal connective tissue		Connective tissues, subcutaneous, subconjunctival, or in the deeper parts of the limbs		Left side of heart.	
West Indies		West Africa		Brazil.	

(2) *Periodicity.*—The periodical recurrence of some of the embryos is a striking phenomenon. In the case of *F. bancrofti* it is definitely nocturnal, though a reversal of the habits of the host will lead to a reversal of the habits of the parasite (fig. 52). The embryo is often called *Microfilaria nocturna.* In *F. loa* the periodical recurrence is in the daytime, and hence the embryo is known as *Microfilaria diurna* (fig. 53).

In the Philippines and in Fiji the embryos have no definite periodicity, and though in other respects they closely resemble *Mf. nocturna,* are possibly a distinct species, and the embryos are described as those of the *F. philippinensis* (figs. 54 and 55.)

Bahr suggests that the absence of periodicity may be connected with the day-biting habits of the intermediate host, *S. pseudoscutellaris.*

In determining periodicity it is essential that measured amounts of blood should be taken.

These three filarial embryos are all enclosed in a loose sheath, and in life are indistinguishable from each other. The measurements of the freshly dead, but not dried, embryos are identical.

(3) The filarial embryos not enclosed in a loose sheath show no periodicity. These are readily distinguished from each other, as in *F. perstans* the thin end tapers to a blunt termination, whilst in *F. demarquayi* (and *F. ozzardi*) the termination is an extremely fine-pointed tail. In the sheathed human filaria the tail end is pointed, but is said to be less so in the embryos in the Philippines than in the others.

(4) All the embryos have a core composed of nuclei which stain deeply with hæmalum or other basic stains. This nuclear core does not extend to either extremity of the embryo.

The termination of this core at the head—blunt end—differs in the sheathed filaria. In *Mf. diurna,* the nuclei are more closely packed together, are larger, oval, and stain poorly, and anteriorly the core terminates abruptly,

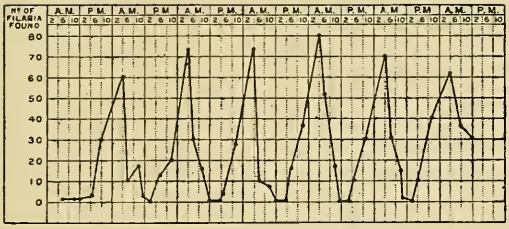


FIG. 52.—Showing nocturnal periodicity, China. (After Manson.)

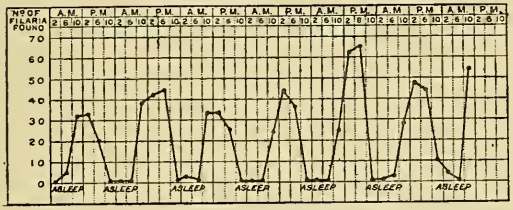


FIG. 53.—Diurnal periodicity, West Africa. (After P. H. Bahr.)

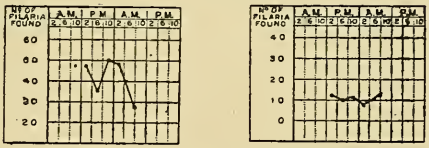


FIG. 54.—Absence of periodicity, two cases, Fiji. (After B. M. Wilson.)

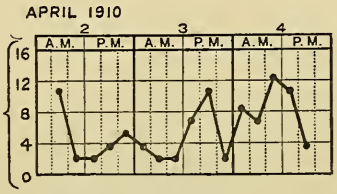


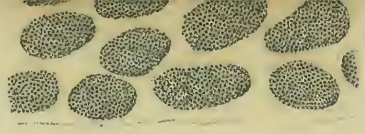
FIG. 55.—Number of filarial embryos in 1 c.mm. of blood in a Fijian. Absence of definite periodicity. (After P. H. Bahr.)

DESCRIPTION OF PLATE I.

1. *Mf. diurna* ? embryo *Filaria loa.*
2. *Mf. philippinensis* ,, *Filaria philippinensis.*
3. *Mf. nocturna* ,, *Filaria bancrofti.*
4. *Mf. perstans* ,, *Filaria perstans.*
5. *Mf. demarquayi* ,, *Filaria demarquayi.*
6. Portion of uterine tube of *F. bancrofti* showing eggs.
7. Portion of uterine tube of *F. bancrofti* showing embryos coiled up in egg-capsules.

Plate I.

4



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7

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Bale & Danielsson Ltd Lith

whilst in *Mf. nocturna* and the embryos of *F. philippinensis* (?) there are detached nuclei at the anterior termination and the nuclei are smaller, more rounded and stain more clearly. (Plate I.)

(5) Measurement of the living or freshly dead embryo differs a good deal from those that have been allowed to dry on a slide. *Mf. diurna* shrinks more than the other sheathed microfilariæ, and therefore in stained specimens is actually smaller, and in proportion to the sheath which does not shrink considerably smaller than the others.

(6) The position assumed by the embryo when dying is capable of being modified by exposure to various vapours, or, as Fulleborn has shown, merely by the rate at which the film is dried. In blood films prepared in the usual way and air-dried there are striking differences. *Mf. nocturna* and *F. philippinensis* (?) die in bold, graceful curves, whilst in *Mf. diurna* the attitude assumed is less graceful, as they are only slightly bent, and often show irregular, angular bends, particularly at the tail end.

Examination of a single embryo may lead to an incorrect conclusion occasionally, but in the majority of instances it is easy to distinguish *Mf. diurna* from the other two. Between *Mf. nocturna* and *F. philippinensis* (?), except for the periodicity, no constant appreciable differences can be observed.

Between the sharp-pointed, sheathless embryos of *F. demarquayi* and *F. ozzardi* no differences can be observed. It is doubtful if they are distinct species.

It is noteworthy that *F. loa* and *F. bancrofti* have few points of resemblance, though their embryos are indistinguishable from their appearance and measurements whilst alive, and when dead and stained are recognized only by minor differences. Fulleborn has shown that there are further differences in the nuclei and cells, both excretory and genital, contained in the nuclear core which are developed when "vital" stains are used.

Exclusion.—It is often important in obscure cases to be able to exclude the possibility of even a small infection

with filaria. By frequent examinations of thick films at different times this exclusion may be made. Absence of eosinophilia confirms a negative diagnosis.

Name of embryo	Length	Greatest thickness	Sheath	Shape of tail	Periodicity	Distance of head gap from head	Adult (known or suspected)
	mm.	mm.				mm.	
Microfilaria nocturna	·317	·0075	Present	Sharply pointed	Nocturnal in peripheral blood	·052	*F. bancrofti.*
Microfilaria diurna	·317	·007	Present	Sharply pointed	Diurnal in peripheral blood	—	*F. loa.*
Microfilaria perstans	·195	·0045	Absent	Blunt, truncated	None	·03	*F. perstans.*
Microfilaria demarquayi	·21	·005	Absent	Sharply pointed	None	·03	*F. demarquayi.*
Microfilaria ozzardi	·21	·005	Absent	Sharply pointed	None	·03	*F. ozzardi.*

Probably the last two are the same, and as the name *F. demarquayi* had been previously employed, the worm should be known as *F. ozzardi.*

Filaria magalhães̄i.—Specimens of this worm, probably an accidental parasite, were found in the left side of the heart in a child in Brazil. Many of the current descriptions of *F. bancrofti* are descriptions of this worm. No corresponding embryos are known.

CHAPTER XI.

FILARIÆ WHOSE EMBRYOS ARE NOT FOUND IN THE BLOOD.

Guinea-worm.—This filaria differs in so many respects from the other filariidæ that it must be placed in a separate group, and the old generic name *Dracunculus* (Kampfer, 1694) should be retained. These worms have been found in several animals, horses, dogs, leopards, &c., but are probably in the main parasites of man (fig. 56).

Dracunculus medinensis in its mature form has a mouth and œsophagus, but the intestine is rudimentary and there is no anus. Only one uterine tube is found, and this opens close to the mouth. When quite mature the whole length of this uterine tube is distended with fluid containing the free embryos (fig. 58). The mouth is terminal and surrounded by two large and four small papillæ. The tail terminates abruptly in a small, sharply bent hook. The males were found by Leiper in an infected monkey. They were very small, 22 mm. in length, and were found under the peritoneum quite separate from the females. There were five pairs of post-anal papillæ.

The adult filaria averages about 40 in. in length, but varies considerably, as some specimens are only 1 ft. and others 5 or even 6 ft. in length. Instances of much greater length are recorded in early writings, but these measurements are much in excess of any recorded in modern times.

During the greater part of its stay in the body it causes no symptoms, but when mature it perforates the skin of the host and escapes, in part, from the body. It is the

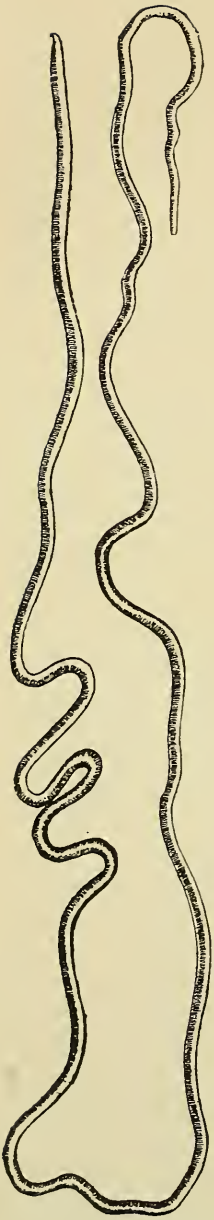


FIG. 56. — Guinea-worm (*Filaria medinensis*). (After Leuckart.)

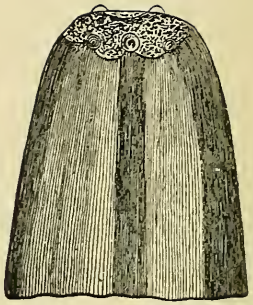


FIG. 57. — Anterior extremity of Guinea-worm. (After Leuckart.)

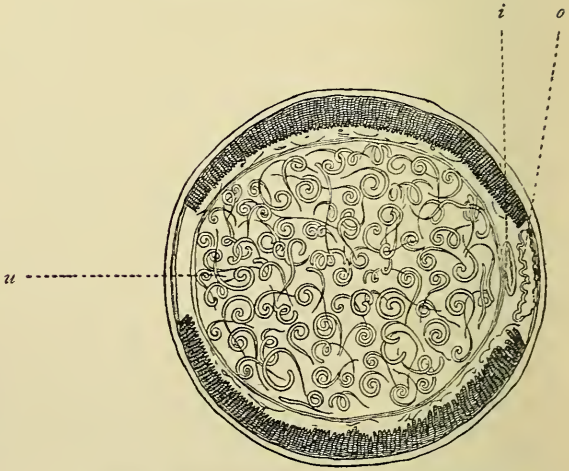


FIG. 58.—Transverse section of female Guinea-worm. *u*, Uterus containing embryos; *i*, intestinal canal; *o*, ovary. (After Leuckart.)

largest of the human filariæ, and causes much pain and a great deal of disablement. Where the worm is common a serious loss of labour is the result.

The effect of the infection of the host is frequently known as *Dracontiasis*. Rarely the worm, before it is sexually mature, may enter an unusual place, such as the knee-joint, and cause serious trouble. In the ordinary course of events when mature it approaches the skin, so that the head is immediately below the cuticle. This

FIG. 59.—On the one foot is to be seen the large blister formed when the Guinea-worm is mature; on the other a blister has burst, a raw surface is exposed, and the head of the Guinea-worm may be seen protruding.

takes place some eleven to twelve months after infection. When quite mature probably an irritating fluid is discharged by the worm in the subcutaneous tissues. A blister then forms, often an inch in diameter (fig. 59). This blister bursts in a day or two, and the head of the worm may be seen at the bottom of a small pit in the raw surface left. If the part is placed in cold water, or water dashed on the skin close to the blister, the head of the worm will be protruded further through the opening. If the head be carefully watched it will be seen that a bladder-like protuberance forms from time to time in front, bursts, and discharges a milky fluid. At one time

this was supposed to be part of the uterus protruded through the mouth, but Leiper has shown that it is through an opening close to the mouth and not the mouth itself. In this milky fluid innumerable embryos are present. The process can be repeated at intervals when the leg is brought into contact with water : in the intervals, as a rule, no embryos are discharged. The object attained is clear ; when the embryos can be discharged into water the parent worm discharges them. At this stage there is some inflammatory swelling round the aperture, but this is usually slight.

By constant repetition of these discharges of larvæ the Guinea-worm empties itself and can be gradually and slowly withdrawn. The inflammation increases from the first, so that the patient is unable to walk. Frequently by injudicious attempts at extraction the worm is killed or broken. The broken end is withdrawn into the connective tissue, and in these cases the embryos are discharged into the connective tissue of the host, and severe inflammation, often with abscess formation, is set up and may extend along the whole of the sinuous track occupied by the worm. Complete disablement then occurs, and there may even be general septicæmia.

The native method of extraction of the worm aims at avoiding these complications by withdrawing the worm very gradually. The head when it emerges is seized and caught in the fork made by partially splitting a piece of wood, or it may be tied to a piece of twine. The worm is rolled up on the piece of wood, a small stick, only slight traction being exercised. The erxtaction of the worm may be aided by dashing cold water on the skin, when more of the worm will protrude and can be coiled up. The stick with the worm coiled on it is fixed close to the opening and secured. In a few hours more of the worm will have protruded, and this part can also be rolled on to the stick. The wound usually heals rapidly. Provided no accident has occurred this method is good, and if the opening is kept aseptic is highly successful. Some authorities endeavour

to improve on this method by killing the worm by injection of various substances; solution of perchloride of mercury, 1 in 1,000, is that most commonly used. The worm thus killed can often be readily extracted. Hot fomentations relieve the pain and reduce the swelling; boracic acid fomentations are those most commonly used.

Excision of the worm is difficult and should not be attempted. Very extensive incisions are required and a great part of the worm may not be superficial. If the worm is broken it may be advisable to slit up the sinus and try to find the broken end, and by traction on this the worm may be extracted in the usual manner. Abscesses, if they form, and general cellulitis must be treated in accordance with general surgical principles.

Etiology.—In the case of this worm the manner in which the larvæ are discharged clearly indicates that the next stage of their existence is passed in water. In water, however, though at first active they only live for a few days, less than a week, and undergo no development. Experiments on monkeys have not given any proof that such larvæ, if swallowed, will infect them.

An intermediate host is required. Fedschenko showed that they were capable of entering the body of a small fresh-water crustacean, a cyclops, and that in this animal the larvæ cast their sheaths and become quiescent. This first ecdysis, according to Leiper, in West Africa occurs about the eighth day; in a colder climate, as in England, probably with a different cyclops, Manson found it to occur in the sixth week. A second ecdysis occurs two days later, and internal development is continued up to the second to fifth week in West Africa. No further changes occur, the larva appearing to have reached its final development in its crustacean host. It does not naturally leave its host, and even if the cyclops dies these Guinea-worm larvæ remain in it.

Many observers had discussed the question as to the further fate of the larvæ, some holding that the embryos penetrated the skin of man and then further developed, so that infection of man took place whilst he was bathing.

Leiper, in addition to showing that the larvæ did not escape from the cyclops under natural conditions, showed that if these infected cyclops were placed in water containing hydrochloric acid to the extent of 0·2 per cent., the equivalent of the acidity of the gastric juice during healthy digestion, the cyclops became motionless and died, whilst the Guinea-worm larvæ became active and escaped from the body of the cyclops. This pointed to infection taking place by the infected cyclops being swallowed and the embryos stimulated in this way becoming active, and then passing from the stomach into the tissues. He fed a monkey on cyclops infected five weeks previously, and in this monkey, which died six months later in England, three immature females, which closely resembled in all essentials the *Dracunculus* (*Filaria*) *medinensis*, and two males were found. As from numerous observations it is known that nearly a year elapses before Guinea-worms mature in man, these immature worms must have been derived from the cyclops.

The course of events is therefore clear. The embryos are discharged by the parental forms in the water in which men bathe. The cyclops in this water serve as intermediate hosts, and these cyclops about five weeks later contain mature larvæ. If swallowed by man they are set free in the stomach, and in the course of a year make their appearance as adult fertilized females, full of embryos, beneath the cuticle, which they perforate. They can then discharge the embryos into the water in which man bathes, and infect a fresh generation of cyclops.

Prophylaxis.—There are three measures which may be considered: (1) Destruction of cyclops. (2) Prevention of the infection of the intermediate host—cyclops—by prevention of persons with Guinea-worm bathing in water containing these cyclops. (3) Prevention of infection of man by infected cyclops. The last is the most practical method. It involves drinking only water in which bathing has not been permitted, or the boiling of such water before use.

As regards (1) the destruction of cyclops, it would be difficult in places used for bathing. Possibly, as Alcock points out, the addition of a small quantity of liquor potassæ might be successful, or injection of steam so as to raise the temperature of the water sufficiently to kill the cyclops, as proposed by Leiper, may be practicable in some places. The simple practical manner of dealing with the question is that water used for bathing should be distinct from that used for drinking purposes. Where water is limited, or sufficient control over the use of water cannot be maintained, the wells must be so constructed that water used for bathing does not flow back into the well, and that people, in obtaining water for drinking purposes, are not able to enter the water, but draw it up by bucket or pump. A good pipe supply from water that cannot be contaminated by bathing should be supplied in all the larger stations.

Onchocerca (Filaria) Volvulus.

Filaria volvulus is a not uncommon parasite in parts of West Africa, particularly in Nigeria and the Cameroons, and in inland districts. Cases have also been reported from the Congo.

Clinically the characteristic of the infection is the formation of subcutaneous fibroid tumours varying in size from a split pea to a hen's egg (Parsons). These tumours are frequently multiple, and are more common on the chest than elsewhere, but may occur in any part of the body. They are not painful or tender, they do not suppurate, and they cause no general symptoms. The tumours are freely movable over the subjacent tissues, but are more closely connected with the skin. They can, as a rule, easily be enucleated, but Gray reports two cases in which the tumours were firmly attached to the periosteum—once to that of the pubis when the tumour simulated a hernia, and once to the sacrum. The tumours consist of a dense fibrous capsule, and in the

interior is a loose fibrous stroma, in which a mass of worms is embedded. The central part is more of a cavity, with a few strands of fibrous tissue, and portions of the worms, including free extremities, occupy the space. A little grumous fluid exudes when the tumour is incised. The nature of the tumour is almost identical with that of the tumours caused by the *Spiroptera reticulata* in cattle and horses. Eggs and embryos are found in the fluid in the tumours, but not in the blood or elsewhere as a rule, though they have been found in the scrapings of the skin by Brienl in similar infections of cattle, and may therefore leave the body by penetrating the skin.

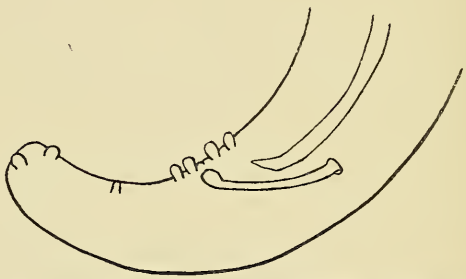


FIG. 60.—Tail end of male *Filaria volvulus*. (After Parsons.)

The male is 20 to 32 mm. in length by 0·2 mm. at its broadest part. The œsophagus is 0·8 mm. in length and shows no dilatation. There is a single spiral twist at the caudal extremity, which is blunt. There are two pairs of pre-anal and two pairs of post-anal papillæ close to and almost touching each other. There are also two pairs of papillæ near the tip of the tail, one pair terminal and lateral and the other sub-terminal and ventral. A single unpaired papilla has been noted midway between the cloaca and the tip of the tail. There are two unequal spicules (fig. 60.) The female is much larger than the male, probably over 100 mm., but is difficult to extract entire. In breadth it is over 0·3 mm. The genital pore is 0·65 mm. from the head. In both sexes there are cuticular thickenings producing an appearance of banding.

The embryos are sheathless, and have a thicker cuticle than most of the filarial embryos. These filariæ have of late attracted a considerable amount of attention as similar tumours are found in the tissues of cattle in Queensland due to an allied species of worm.

Other filariæ that have been described were probably accidental parasites in man, and are of rare occurrence; amongst these are :—

Filaria oculi humani, doubtfully a worm at all, and only found in an immature condition by Kubent in 1891. Another filaria or immature form belonging to some other family has been found in the posterior chamber of the eye.

F. conjunctivæ, a normal parasite of the horse, has been described in man.

F. restiformis is the name given to a worm 16 mm. in length and 1·5 mm. in breadth passed with the urine by a man in West Virginia.

F. hominis oris and *F. labialis*, 14 mm. and 30 mm. respectively in length, have only once been found.

F. equina or *papillosa* is a common parasite of horses and is found in the peritoneal cavity. A worm similar to this has been found in man on a few occasions.

These filariæ are mentioned, but the evidence of their existence and of specific characters is not always sufficient.

Agamofilaria georgiana (Stiles).—Immature female worms, removed from the ankle of a negress. They caused local pain and swelling, and emerged through the skin without any assistance. These immature worms were 32 to 53 mm. in length. Mouth terminal, unarmed, but surrounded by six papillæ. The œsophagus was long 2·5 to 2·9 mm.; no dilatations. Intestine nearly straight. No genital organs found.

MERMIS.

Gordiacea or *Mermithidæ*.—A family of long filiform worms in which there is no anus. There are six oral papillæ. The caudal extremity of the worm is very long.

In the males there are two spicules and three rows of papillæ, which are numerous. These worms are parasitic in the body-cavity of various insects and when the full larval development is reached escape and become sexually mature in the non-parasitic state. The embryos enter the insects whilst these are in their larval stage. These worms are not uncommon in the vicinity of houses, and are frequently mistaken for filariæ, &c. They are found in various regions in the Tropics. They are not parasitic in man, but are so often sent home, sometimes as specimens of Guinea-worms, that they are deserving of mention.

CHAPTER XII.

TRICHOTRACHELIDÆ.

THE family *Trichotrachelidæ* are distinguished by the anterior part of the body being long and thin, whilst the posterior is broader and rounded posteriorly. The anus is terminal. The œsophagus is long and straight without any expansions.

The females have only one ovary and the genital pore or opening of the ovarian tube is situated at the junction of the thick posterior part with the thin anterior. In the males there is only one spicule and the vas deferens opens into the cloaca.

There are two genera, represented by one of each species, in man—*Trichocephalus* and *Trichinella*. In Trichocephalus the anterior part is very thin and thread-like, and the junction with the thicker posterior part is abrupt. They are vulgarly known as whipworms. The eggs are oval and have a thick outer capsule, brown in colour, with an opening at each end. Development is direct, the embryo is slowly developed in the shell and when the eggs containing these larvæ are swallowed by man the shell is dissolved off and the larvæ are set free and attach themselves to the intestinal wall and become sexually mature. No alternative host is required. Various species of Trichocephalus inhabit the intestines, either the large or small intestine, of mammalia. That in dogs is known as *Trichocephalus depressiusculus*.

Trichocephali also occur in several species of monkeys, in cats, &c.

In man one species is known, the *Trichocephalus trichiurus* or *T. dispar*.

The female is 50 mm. in length and the male about 45 mm. They are found in the cæcum, and occasionally, when numerous, in the ascending and transverse colon—rarely in the vermiform appendix.

Three-fifths of each worm are formed by the thread-like anterior extremity. The mouth is unarmed, and the anterior two-fifths contain the long œsophagus which

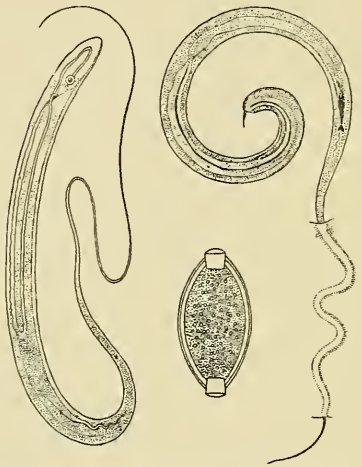


FIG. 61.—*Trichocephalus trichiurus*. On the right, male; on the left, female. Below, egg.

appears to be moniliform. A considerable length of the thin anterior end may be embedded in the intestinal mucosa. In the female the genital opening is just at the well-marked junction of the broad and thin parts of the worm. The ovary is posterior. The caudal extremity of the male is sharply curved on itself, and from the cloaca may be extruded a rounded projection in the summit of which is the opening of the vas deferens (fig. 61.)

Trichocephalus trichiurus is found in temperate climates but is much more common in inhabitants of tropical countries. Usually only a few worms are present in each individual.

There is no proof that any disease is caused by the trichocephali. Persons harbouring the parasites may be in perfect health. Cerebral symptoms are said to have been caused by the worms when present in large numbers, but such manifestations are exceptional, even if they ever cause them. They have been suggested as a cause of appendicitis, and the worms may be found in the appendix, but appendicitis is more common in countries where the trichocephali are rarely found than in the Tropics where they are commonly found. There does not seem to be anything in support of this hypothesis. The actual injury done to the intestinal wall is inappreciable, and no ecchymoses are formed round the point of fixation.

Treatment.—Thymol, or the mixture of eucalyptus oil, chloroform and castor-oil given for ankylostomes and other worms (p. 153), frequently causes the expulsion of trichocephali.

Etiology.—The eggs are passed in the fæces. They are very resistant and may retain their vitality for years. The embryo develops in the shell more rapidly in warm weather. By the time development is complete the fæces will have been completely destroyed and the eggs scattered widely. The eggs are not destroyed by passage through the intestines of larvæ of Muscidæ, by ordinary air-drying, nor during the decomposition of fæces.

Prophylaxis would be difficult by any of the ordinary methods of dealing with excreta, particularly if they are required for use as manure after more or less decomposition. Thorough cooking of green vegetables or ground crops would destroy the eggs, whether they contained embryos or not. The contamination with earth of any food or of utensils used in preparing or serving food should also be prevented. Trichocephalus eggs are not proof of direct sewage contamination, as they may be derived from fæces that have been completely destroyed, and may be blown about with dust into water supplies.

Trichinella.

Trichinella.—The thin and thick portions of the worm merge gradually into each other. There is not the abrupt transition as in the Trichocephali. The females are vivi-

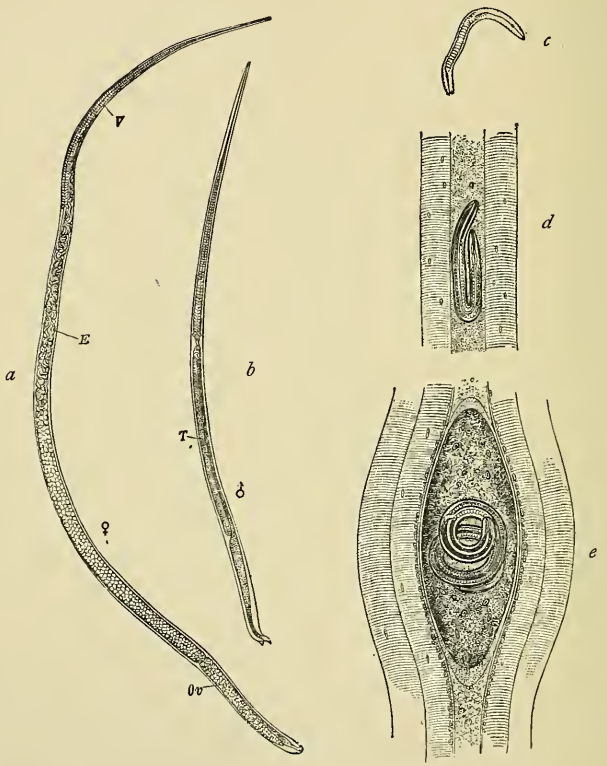


Fig. 62.—*Trichinella spiralis.* *a*, mature female, "intestinal trichina"; *E*, embryos; *V*, vulva; *Ov*, ovary; *b*, mature male, "intestinal trichina"; *T*, testes; *c*, newly-born larva; *d*, larva of trichinella in the muscles; *e*, encapsulated trichinella of the muscles. (After Claus.)

parous and in their whole existence the worms are parasitic. Two mammalian hosts, not necessarily of different species, are required for the development.

Females measure 3 to 4 mm. in length and 0·05 mm. in

diameter. The anus is terminal, the mouth is unarmed, and the vaginal opening at the junction of the anterior fifth with the rest of the body. There is only one ovary. The males are smaller, about 1·5 mm. in length and about 0·04 mm. in diameter. The cloaca is terminal and lies between two caudal appendages. There are four post-anal papillæ but there is no spicule.

Trichinella spiralis or *Trichina spiralis* (fig. 62) in its sexual mature form may be found in man, but ordinarily is a parasite of rats or pigs. Many animals, both carnivora and herbivora, may be artificially infected. In man infection is usually derived from pork, and the disease caused is a serious one.

The Trichina larvæ encysted in the pork are still alive when swallowed by man, unless they have been destroyed in the process of cooking or otherwise preparing the flesh of the pig for food. The larvæ are set free in the stomach and intestine. There they become active, and in the duodenum and jejunum they become sexually mature. The increase in size is not great, for the larvæ measure about 0·8 mm. in length, whilst when first sexually mature they are only 1·5 to 1·8 mm., and the males 1·0 to 1·2 mm. Copulation takes place in about two days after the ingestion of the larvæ, and the males soon die, whilst the females continue to increase in size, and in the course of a few days they nearly double their length. They bore their way more or less deeply into Lieberkuhn's glands, into the mucosa, and ultimately into the lymphatic spaces. In these spaces they pass their larvæ, which at first are only 0·09 mm. in length. They are carried mainly by the lymph and blood to various parts of the body, but some appear to pass through the tissues and into the peritoneal cavity. In either case they ultimately come to rest in striated muscle. These larvæ reach their final destination in about nine days after the infected pork has been ingested, but as the female trichinella lives for five or seven weeks and continues to pass larvæ in numbers, the symptoms may

continue during the whole of this period. These symptoms may be general abdominal pain or tenderness associated with pyrexia and may at this stage be mistaken for enteric fever or for peritonitis.

The invasion of the muscles is usually associated with muscular tenderness, rendering movements acutely painful, and if the muscles of respiration, mastication, or deglutition are invaded there may be serious difficulty in respiration or in taking food.

There is frequently diarrhœa, and fugitive œdematous swellings, particularly under the eyes, may be present. Blood examination will show marked eosinophilia. The larvæ are not found in the peripheral blood.

The larvæ when they reach the voluntary muscles become quiescent and encysted and then cause no further trouble. They increase in size up to 0·8 to 1 mm. in about three weeks and may remain alive for years, but undergo no further development. The cysts are formed at the expense of the muscle-fibre and connective tissue, and adipose tissue collects at the poles. The cyst wall ultimately calcifies in many cases. The cysts are just visible with the naked eye.

Prognosis is usually good, but fatal peritonitis may occur in a very large infection.

Treatment.—This must be purely symptomatic. The adult worms are too deeply embedded in the tissues for intestinal anthelmintics to be of any value.

Etiology.—The animals that serve as definitive hosts may also serve as intermediate hosts. The sexual stage is passed in or near the intestine, whilst the development of the larvæ takes place in the voluntary muscles of the same animals. Any susceptible animals, such as man, the rat, pig, &c., may be infected by eating the uncooked flesh of the same species, or of infected animals of other species. Man is probably always infected from the flesh of pigs by eating pork, or as the embryos may be encysted in the intestinal walls of the pig by eating the skin of sausages if these are the intestine of that animal. The pig is usually

infected by eating dead rats, but sometimes may be infected by eating the refuse scraps from a slaughter-house where pigs are killed. The infection in rats is maintained by their eating each other. The diaphragm in rats is the common site of infection.

Prophylaxis.—The association of rats and pigs is a common one and is difficult to prevent, but every effort should be made to destroy rats near pigsties. Pigs should never be fed with the refuse from pork butchers' shops or slaughter-houses. Thorough cooking of the meat kills the embryos, but the temperature of all parts must be raised to 62° to 70° C. This temperature is not necessarily attained in cooking large joints. In certain sausages uncooked pork is used. Inspection of pork is not always practised, nor sufficiently thoroughly, especially in pork intended for export. "Trichinosed pork," or "measly pork," is not allowed to be sold for human consumption when the condition is detected. The parts most commonly affected are the tongue, muscles of the larynx, the diaphragm, and abdominal muscles. These should always be inspected and if trichinæ are found in them the whole carcass should be condemned. In the inspection small portions of the meat, preferably from the tongue, larynx, and diaphragm, are squeezed between two glass plates so as to be translucent. The encysted larvæ can then be readily seen with or without a hand-glass.

Trichinosis is very rare in England and France, more common in Germany, and in some parts of America. There is no information as to its frequency in most tropical countries, but it occurs amongst the pigs in both India and China. In Mahomedan countries pork is not eaten by natives, and Europeans rarely eat pork in the Tropics. There is at present little trade in frozen pork, but what there is is mainly from China, and in some parts of China a large proportion of the pigs are infected, but it should be remembered that the trichina larvæ are not killed by freezing.

CHAPTER XIII.

STRONGYLIDÆ.

Strongylidæ.—Armed or unarmed mouths, no pharyngeal bulb. In the males the cloaca is terminal and surrounded by a membranous expansion, strengthened in most instances by chitinous thickenings — copulatory bursa. There are one or two spicules, when two they are equal. Larvæ frequently rhabditiform.

The family includes a very large number of species, many of which are parasitic. An intermediate host is not required as the development of the larva from the egg takes place in the earth or water, and the parasitic life is resumed only when the larvæ have developed to some extent. The most important genera of the Strongylidæ parasitic in man are *Eustrongylus*, *Strongylus*, *Ankylostomum*, *Œsophagostomum* and *Triodontophorus*.

Eustrongylus.—Large worms found in the pelvis of the kidney, and sometimes in the abdominal cavities, of various animals. In the male the copulatory bursa completely surrounds the cloaca as a collar-like process with thickened edge—but without strengthening ribs—in which are papillæ. There is only one spicule. In the female there is a single ovary, and the opening of the vagina is in the anterior half of the body.

One species, *Eustrongylus gigas*, a parasite of dogs, seals, &c., has been described as occurring in man. The male is 40 mm. in length, and the female up to 70 mm. The spicule of the male is 5 to 6 mm. long.

The eggs are oval and at the poles clear and colourless, but elsewhere brown and thick-shelled, presenting numerous depressions. They measure 0·064 by 0·05 mm. An embryo slowly develops if the eggs be kept in moist earth for months, but the further life-history is not known.

Strongylus. — Common in the domesticated animals. Many of them live in the bronchial tubes, such as *Strongylus micrurus*, so common in the lungs of cattle in America and Africa. In young animals fatal bronchopneumonia is caused. Older animals acquire tolerance. *S. apri*, common in pigs, has been found in man. *S. longevaginatus* has been once found in man ; and it is suggested that other nematodes found in the human lungs may belong to this group.

S. subtilis occurs in the human intestine in Egypt and Japan. It is also found in the camel. The males are 4 to 5 mm. in length, and anteriorly measure 0·009 mm., but posteriorly, close to the bursa, 0·07 mm. The œsophagus is rather less than one-sixth of the length of the body. The copulatory bursa consists of two lateral flaps strengthened by asymmetrical ribs.

The females are 5·6 to 7 mm. in length and about 0·09 mm. in breadth. The anus is subterminal and the caudal extremity tapers suddenly to a slender pointed tail. The genital opening is at the junction of the posterior fifth with the rest of the body.

Metastrongylus apri recognized by Joitsits in 1845 as a parasite closely allied to the lung parasite of pigs and named by him *S. longevaginatus*. They were found in the lungs of a boy aged 6 in Transylvania.

Other *Strongylidæ* found in man mainly belong to the group Sclerostominæ. Mouth furnished with a complex chitinous armature. The mouth opens directly in most genera into a dilated portion, the *buccal capsule*, to which the armature is attached and then opens in the œsophagus. The *bursa copulatrix* is strengthened by ribs.

The family is subdivided into genera mainly on the varying characteristics of the mouth-parts and of the caudal bursa of the male.

Ankylostomiasis.

Ankylostomiasis is the disease attributed to the *Ankylostomum duodenale*, or the *Necator americanus*, and is a

progressive anæmia of a severe type, associated with fatty degeneration of the heart, liver and kidneys, and of the mucosa of the alimentary canal. It may terminate fatally from the anæmia, from cardiac failure, or from intercurrent diseases, such as dysentery. In early cases recovery is rapid and complete when the worms are expelled.

These two species of worms appear to produce the same effects, and therefore the term Ankylostomiasis is used indifferently whether the *A. duodenale* or the *N. americanus* is responsible.

These worms belong to the division in which there is a deep oral capsule. In this division the mouth opens into a cavity and in this the opening of the œsophagus is situated. There are frequently armatures, such as teeth, thickenings, or spines, at the orifice of the buccal or oral capsule, and sometimes of the orifice of the œsophagus as well.

In most of the genera the lips of this oral capsule are symmetrical, but in the Ankylostomes the ventral side is longer than the dorsal, and in addition the head is bent towards the dorsum so that the opening of the oral capsule is directed dorsally.

The opening of the female genital organs is near the middle and in the female the anus is subterminal, the tip of the tail being bluntly pointed.

The male is smaller, the cloaca is terminal and surrounded by four membranous flaps strengthened by chitinous ribs forming the copulatory bursa. There are two long equal spicules.

Ankylostomum duodenale.—Female, 10 to 13 mm., by 1 mm. in breadth. Occasionally larger specimens up to 20 mm. are met with. Male, 9 to 12 mm., and 0·5 mm. in breadth (figs. 63 and 64).

Necator americanus is smaller and more slender. Female, 9 to 11 mm., by 0·5 mm. in breadth. Male, 7 to 9 mm., by 0·35 mm. in breadth.

They can be distinguished without measurements by the naked eye, as in Necator the head is more abruptly

FIG. 63.—*m*, *f*, male and female Ankylostomes; *a*, head of *Ankylostomum duodenale*; *b*, head of *Necator americanus*.

bent back in both sexes, and in the male the copulatory bursa is not median but directed to one side. The oral capsule is smaller and rounder in *N. americanus* (fig. 63, A and B).

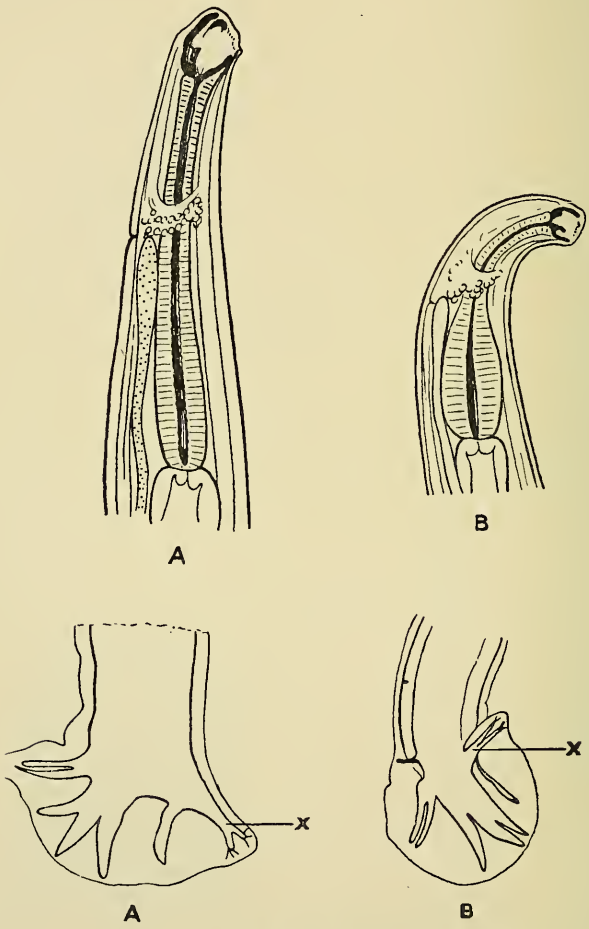


FIG. 64.—A, A, head and tail of male, *Ankylostomum duodenale;* B, B, head and tail of male *Necator americanus;* X, X, dorsal rays.

When examined closely more important differences are found. The armature of the buccal capsule consists

of two pairs of curved teeth attached to the ventral edge in the Ankylostome, whilst in Necator there are no teeth, only thickening of this edge of the capsule. The genital opening in the female is behind the middle line in Ankylostome and in front of it in Necator.

In the male the rib supporting the mediodorsal lobe of the caudal bursa, the dorsal ray, is of special importance. In *N. americanus* it divides near the base and the tips of each branch divide into two. In *A. duodenale* the dorsal ray divides more than half-way up, and the tips of each division divide into three (fig. 64 and A and B.)

Geographical Distribution.—The disease occurs in most tropical and subtropical countries amongst those who work on ground contaminated with the evacuations of persons harbouring these parasites. It is therefore common on sugar estates, amongst those occupied with public works, roads, railways, &c., and amongst miners.

Further north, as in England and the North of Europe, it only occurs amongst those working in underground mines, as the temperature on the surface of the earth is not sufficient for the development of the worm.

No race is exempt, but the conditions of life for Europeans in the Tropics are such that the liability to infection is slight. The disease occurs in all the continents and in most of the islands in the Tropics. In many places, either directly or indirectly, it is a cause of a large proportion of the total mortality.

Clinical Course.—The onset of the progressive anæmia is insidious; frequently it commences shortly after convalescence from some other disease, such as dysentery or malaria. In other cases there may be febrile symptoms in the early stages, but often there are no symptoms at all. The patient notices increasing breathlessness on slight exertion, and debility, and is found on examination to be markedly anæmic. On plantations the money he earns becomes steadily less.

This anæmia steadily increases so that the patient becomes breathless on the slightest exertion and utterly

incapable of any work. Sometimes there is epigastric pain. The appetite remains good, but there may be perverseness such as "geophagy." There is no diminution of the subcutaneous fat. There are no nerve symptoms, though the patient may become lethargic. Œdema, at first of the feet only, is the rule, and general anasarca occurs in the later stages.

Constipation is common; the motions are usually formed and appear normal to the naked eye. Sometimes there is much mucus discharged which is not blood stained. On microscopical examination eggs of the ankylostome will be readily found. Fatty crystals are frequently present, and in the later stages much undigested food. In other cases there is diarrhœa, and the stools may then contain much undigested food. Chronic intestinal catarrh is a frequent complication. The urine is free from albumin, but occasionally, near the end, there may be albuminuria.

The most prominent symptoms are those of anæmia and those due to fatty degeneration.

The anæmia is produced so slowly that the patients rarely seek advice till it is marked. Before this a certain disinclination or disability to work will have occurred. In native labourers, on piece-work, it is often found that their earnings have been steadily diminishing for weeks or months. In such cases the mucous membranes, not only of the conjunctiva but elsewhere, may be almost white and slightly œdematous. The tongue is very pale and usually indented by the teeth. In coloured races the pigmented patches, so common in that situation, but difficult to see against the normal red tongue, are now very clearly visible. The lips are pale and bloodless, and in a European the skin appears to be absolutely white, and often of a peculiar waxy appearance. No tinge of colour will be seen under the nails. In the Negro the pallor is obscured to some extent by the pigmentation of the skin. In infections early in life growth is stunted and the patients are heavy, lethargic and show little

energy. The physical and mental deterioration of the poorer classes of whites in the Southern States of U.S.A. is to a great extent due to the frequency with which they are infected with this worm.

The Blood.—Both the number of red corpuscles per cubic millimetre and the amount of hæmoglobin are reduced enormously. In some cases, and usually amongst Europeans (Haldane), the reduction in the amount of hæmoglobin is in excess of the reduction in corpuscles. In other cases, and more commonly in natives, the hæmoglobin is either diminished in the same degree or even to a smaller extent than the number of red corpuscles. It is unusual to get as much disproportion as in a typical case of pernicious anæmia. In advanced cases the red corpuscles may be less than 1,000,000 per cubic millimetre, and before death may be less than 500,000. The hæmoglobin may fall to 15 per cent., or, in fatal cases, the reduction may be still greater. The red corpuscles are as a rule more uniform in size and colouring than in pernicious anæmia, and poikilocytosis less marked, but exceptions are not rare. Nucleated red corpuscles are rarely to be found in large numbers. In the opinion of the author, amongst natives the blood changes approximate to those in pernicious anæmia rather than to the chlorotic type. Haldane and Boycott, from their observations on Cornish miners, came to a different conclusion.

The leucocytes are usually not increased, but the relative proportion of eosinophiles is always increased; usually they form some 10 or 12 per cent. of the total leucocytes instead of the normal 2 to 4 per cent. Not uncommonly much higher proportions are observed, such as 30 to 40 per cent., or even more.

The blood coagulates with difficulty, and is so thin and watery that it readily spreads over the skin when a puncture is made. The volume of the blood in advanced cases appears to be diminished.

The fatty degeneration of the viscera forms a serious

element in the pathology of the disease, and the extent to which the change has taken place affects the prognosis.

Fatty degeneration may occur early in the course of the disease, before the anæmia is extreme. The heart is one of the organs earliest affected, and dilatation is very common. This may be accelerated by strain or over-fatigue, and the patient may die suddenly. This occasionally happens to a person straining at stool or taking any violent exertion. Frequently over-fatigue results in a cardiac dilatation, from which the patient does not recover, but dies in a few hours or days.

With the patient absolutely at rest the pulse, though very soft and compressible, may not be fast, but with the slightest exertion it becomes very rapid. Murmurs, at first hæmic, but later definitely due to regurgitation, are developed with slight exertion. Venous pulsation can usually be observed in the neck, as well as a venous hum.

Epigastric pain is a common but not invariable symptom, and may occur early in the disease.

The appetite is usually good, but may be capricious, and in some places earth-eating—geophagy—is common in such patients. Occasionally coal and other abnormal substances may be eaten. In the last stages there may be aversion for food.

When there is constipation the eggs of the worm will be found uniformly distributed throughout the fæces. When there is watery diarrhœa much undigested food is passed, and the eggs will fall to the bottom. These conditions are probably due to the fatty degeneration of cells in the mucosa, and in such cases the prognosis is less favourable. In the liver and kidneys extreme degrees of fatty degeneration are common.

Dysentery as a complication is common. Occasionally there is melæna from the passage of blood into the small intestine, and rarely the hæmorrhage into the intestines is profuse, and death occurs rapidly. In such cases a little altered blood may be passed *per rectum*, or there may be a large quantity. In some cases no blood is passed, but the small intestines may be distended with blood.

The impairment of the digestion is probably not the direct effect of the worms, but partly due to the fatty degeneration and partly to a chronic catarrhal condition associated with an abundant formation of mucus, which is very common in these cases. The fatty degeneration of the liver and kidneys gives rise to no symptoms that can be referred directly to these organs; only in the last stages is there albuminuria. Usually the temperature is subnormal, but in the early stages of infection there appears to be pyrexia, and in some cases there is an irregular pyrexia of a mild type that does not yield to quinine, is not associated with any evidence of malaria, and usually subsides with rest and purgation.

Nervous symptoms are not marked. There is a certain amount of lethargy over and above the natural aversion to exertion in a person with advanced anæmia. There is no paralysis, and the superficial and deep reflexes are normal. Headache and vertigo are not in excess of what might be anticipated from the anæmic condition.

Diagnosis.—The presence of ankylostomes can be diagnosed by finding the characteristic ova in the fæces. The examination is easy and any person of ordinary intelligence can readily be taught to examine the fæces and recognize the eggs. A small portion of the fæces is compressed into a thin layer so as to be translucent and is examined by the microscope. The eggs can be found with an inch objective, but it is better to examine with a half or a quarter inch, to distinguish these eggs from others. The eggs are oval, measuring 0·056 to 0·06 by 0·034 to 0·038 mm. in *Ankylostomum duodenale*, and 0·064 to ·072 by 0·036 mm. in *Necator americanus*. If measurements of the eggs are required care must be taken not to compress the eggs. They have a very thin, transparent, colourless shell, and when freshly passed the contents have commenced to segment into two or four masses. If kept a few hours in a warm place segmentation will be more advanced. If the fæces are too hard to be readily compressed a little water may be added. If the motions

are liquid they should be allowed to stand, and the deposit taken up with a pipette, as the eggs are heavy and sink to the bottom.

The anæmia and the presence of ankylostome eggs in the stool, and the blood changes described, including eosinophilia, are sufficient for diagnosis. In advanced cases the anæmia may persist after the expulsion of the worms. In these cases, without the history, a correct diagnosis cannot be made.

Prognosis.—This is very good in cases where the anæmia has developed rapidly and the patient is young, *provided the worms are completely expelled.* Treatment with anthelmintics is deceptive, unless the fæces are examined a week or so later for eggs, as it frequently happens that only a small proportion of the worms are expelled after their administration, though the remaining worms may not pass eggs for some days. In aged persons, in those who have been anæmic for prolonged periods, and where the digestive functions are imperfect, as shown by the amount of undigested food passed, the results of treatment are less certain. In such persons very successful results may be obtained, but are not so uniform.

In parturient women the prognosis is very grave. This is not only because even a small loss of blood is badly borne by advanced anæmics, but because the prolonged strain and violent exertion lead to cardiac failure. Such patients frequently die shortly after the child is born. There is no tendency to *post-partum* hæmorrhage. Premature labour is common. Children are often stillborn, but may be living and in good condition.

Untreated cases may remain stationary for years, but usually the anæmia steadily increases, and the fatty changes in the viscera result in further impairment of health, and the patients die either from anæmia, from the results of the fatty changes, or from some intercurrent, possibly trivial, disease.

Morbid Anatomy.—The body usually appears to be well nourished, and subcutaneous and peritoneal fat may be

abundant. There is no tendency to early decomposition in uncomplicated cases. Rigor mortis is not well marked.

The voluntary muscles are pale and sodden, and all the organs appear to be anæmic. There is excess of clear fluid in the serous cavities.

The lungs may appear absolutely white, or white streaked with black — the remnants of carbonaceous deposits. If an examination be made within a few hours of death their weight is much below normal — the two together sometimes weighing less than 20 oz. If the examination is delayed they are sodden and œdematous, and may be above normal weight. Vesicular emphysema is common.

The heart is always pale, soft and friable, and there is much fatty degeneration. The cavities are frequently dilated, but there is no muscular hypertrophy, the weight being less than the average.

The liver is sometimes so fatty that it will float in water. The colour, in the most anæmic cases, is best described as "dusky chrome yellow," a term applied to it in 1847 in British Guiana. This tinge is due to the extensive deposits of hæmosiderin or yellow pigment in the hepatic cells. If in addition there has been malaria the colour is modified. When the anæmia or fatty changes are not so advanced the liver may appear as a yellowish brown or red.

The intestines in an advanced case are so anæmic that the mucosa may appear quite white. Small petechiæ are often numerous. These are found round the point of attachment of worms and show a central spot where worms have been attached. Frequently there is abundant adherent mucus covering the mucosa. This may be stained or streaked with blood. The worms are found most abundantly in the jejunum, and become scanty in the ileum, and are very rarely found as low down as the ileo-cæcal valves. A few are usually present in the second and third parts of the duodenum.

On microscopical examination fatty degeneration of the intestinal muscosa, of the liver, kidney and cardiac muscle, is found always to be extensive. In the liver, when it is not universal, only the cells in the centre of the lobules may be invaded. In addition to the abundant deposits of hæmosiderin present in all cases, there may be colourless granules giving the reactions of iron in inorganic combination in the acute cases.

The kidneys may appear of similar dusky chrome colour to the liver. The fatty degeneration affecting the epithelium in the tubules is marked. Deposits of hæmosiderin and iron-bearing granules are most abundant in the epithelial cells of the convoluted tubules.

If the examination be made a few hours after death all the worms will be still attached to the mucosa, but later they become detached and are then found free, either in the mucus or in the contents of the alimentary canal. Very rarely there are small cysts, each containing a single worm usually taken to be an ankylostome, but possibly some other nematode. No opening into the intestine is found in these cysts, and the worms are usually males.

In milder cases, or in persons who show no symptoms of the disease, there may be no marked excess of mucus. In these cases both the worms, and also petechiæ due to old bites, are found. The rare accident of profuse hæmorrhage into the intestinal canal is probably from damage to a small vessel.

The brain shares in the general anæmia. The cerebrospinal fluid is increased in amount.

Treatment.—Good food, rest and tonics are of little or no value unless the worms are expelled, but are important aids to an anthelmintic treatment. In a person in a very weak condition, where there is suspicion of cardiac failure, and in parturient women, immediate anthelmintic treatment is almost certain to be fatal. In such cases attempts must be made to improve the general health before active treatment is commenced. The expulsion of the worms is not an easy matter, and is often successful

only after repeated attempts. Oil of male fern, β-naphthol, thymol, oil of eucalyptus and chloroform are the best to use, and of these the last two are most to be relied upon.

Preliminary treatment is required to remove the mucus which covers and protects the worms. This consists of semi-starvation and purgation. The patient must be kept in bed on low diet for two or three days, and the bowels kept freely open. No food is to be given after 6 p.m. on the night before the administration of the anthelmintic. In the early morning a purgative dose of salts or castor-oil should be given. Some prefer calomel, but it is risky with anæmia, though small doses, $\frac{1}{10}$ to $\frac{1}{8}$ gr. three times a day for two or three days before, may be given in cases where there is no pyorrhœa alveolaris. If thymol be used, 15, 20, or 30 gr., in cachet or wrapped in cigarette paper, should be given and the same dose repeated one or two hours later.

Eucalyptus and chloroform are employed by many :—

Eucalyptus oil or eucalyptol	ℿxxx.
Chloroform	ℿxlv.
Ol. ricini	ʒx.

This should be divided into two doses ; the second dose should be given half to one hour after the first.

In any case a brisk purge, preferably saline, should be given an hour later. The patient can be allowed to take food after the action of the purgative. All the stools for that and the next day should be saved, strained, and examined for the worms. Some worms will always be found, but even if they are numerous the stools must be examined for eggs for some weeks. Usually they are found in about a week, and if found the treatment must be repeated. It is common for it to be necessary to repeat either form of treatment three or four times or more at intervals of one week before the great majority of the worms are expelled. To remove *all* the worms, even with repeated treatment, is difficult.

When this has happened, good, nourishing, easily digested food, and rest are all that is essential for

complete recovery. Tonics, iron and arsenic are advantageous and probably expedite recovery.

It will be seen that the treatment is drastic, and that the prolonged deprivation of food and purgatives must involve some risks in advanced cases. In these the attempt may be made to remove the worms by shortening the period of deprivation of food, but is not often successful, or the treatment must be postponed. Some cases are hopeless. Thymol is occasionally dangerous and may cause collapse, cardiac failure, or delirium. The risk is greater if it is given in solution, and therefore solvents of thymol, such as alcohol and oils, must not be used, nor must they be given to the patient while he is taking the thymol. Chloroform and eucalyptus oil seem to be almost as effective and the mixture is less dangerous and not so unpleasant to take.

Nursing.—Very careful nursing is required in advanced cases of ankylostomiasis and even in mild cases during the active stages of the treatment. The great danger is cardiac failure. No unusual exertion must be allowed in bad cases, or in any whilst under anthelmintic treatment. The patient must not be allowed to leave his bed or sit up. The bowels must be kept regular and the motions should be semi-solid. The patient must not be allowed to strain forcibly. Mild aperients or enemata should be used.

In a cold climate warmth must be maintained by the regular use of hot bottles as well as of warm blankets. The foot of the bed should be raised, and in bad cases the legs should be wrapped in cotton-wool, and bandaged firmly and evenly from below upwards. As in other cases of extreme anæmia alcoholic stimulants are of little value and must not on any account be given after or shortly before the administration of the thymol. Cardiac tonics such as digitalis and strychnia are useful. Opium, best given hypodermically in tonic doses only, is often of considerable value ; $\frac{1}{12}$ or $\frac{1}{10}$ gr. of morphia will often relieve the restlessness, improve the pulse and induce sleep.

Food must be light and nutritious, and must be given regularly at short intervals.

In cases of parturition the patient must not be allowed to leave the bed at any stage of the labour, nor must she be allowed to strain forcibly. If labour is not exceptionally rapid and easy, operative measures are probably indicated. Hæmorrhage is usually slight, but the little loss is still serious. The uterus tends to be atonic and must be supported by the hand as long as there is any tendency to dilatation and for considerably longer than in a healthy person. Active treatment with anthelmintics must be postponed till the patient has recovered from the effects of parturition, and every effort made by careful feeding and nursing to improve the condition. In early pregnancy there is no objection to active treatment, but when near full time there is less chance of a successful result.

Late in pregnancy a modified treatment, with less starvation and purgation, may be tried. It is less dangerous, but not so effective. Eucalyptus mixture is much to be preferred to thymol in these cases.

The improvement in the general condition after the complete removal of the worms is rapid and begins in about a week or so after that event. Usually two or three attempts to expel the worms have to be made, with an interval of a week in between.

Etiology.—The frequency with which severe anæmia occurs in many tropical countries has long attracted attention. It was usually considered to be climatic or due to malaria. Anæmia no doubt may be due to such causes, but the common extreme anæmia is not. The worms had been seen by many, and the associated anæmia noted, but it was not till the epidemic of anæmia in the St. Gothard Tunnel works was shown to be due to the ankylostome that general attention in the Tropics was directed to this form of anæmia. From this period onwards there was much discussion as to the actual causal relationship of the anæmia. It was soon found that the worms were often found in persons showing no anæmic condition, and that they might be numerous in such cases,

Instances were also given of extreme anæmia in persons harbouring very few worms.

It is now generally admitted that the common cause of extreme anæmia in the Tropics is the *Ankylostomum duodenale*, or the closely related *Necator americanus*, for the following reasons :—

(1) That in countries where the ankylostome is common anæmia is common, and in countries and places where ankylostomes are rare dangerous anæmia is as rare as in England, though there are no material differences in climate, amount of malaria, or in the diets in the countries and places.

(2) That in the same country the prevalence of anæmia in different races varies according to the prevalence of ankylostomes in these races.

(3) That in the great majority of the cases of persons suffering from anæmia there is no evidence, clinical or *post mortem*, of any other cause for the anæmia.

(4) The most important and conclusive evidence of the relation being that of cause and effect is that treatment of all other kinds fails to do more than retard the progress of the disease, or to produce slight improvement, whilst expulsion of the worms is followed in a large proportion of the cases by rapid and complete recovery. Administration of thymol, β-naphthol, &c., if it does not remove the worms, is followed by no improvement. In the minority where recovery does not occur, either death occurs too soon for the amelioration to take place, or visceral lesions, particularly fatty degeneration of the intestinal mucosa, are so extensive that the removal of the primary cause could not be expected to be successful in relieving the patient.

It is admitted that numerous ankylostomes do not *necessarily* produce profound or even slight anæmia; but in the great majority of cases where there are numerous worms there is marked anæmia.

The manner in which the anæmia is produced has also been the subject of some discussion. The earlier supposition was that the Ankylostoma was a blood-sucking

worm, and that the anæmia was the result of repeated small losses of blood.

When it was found that the black contents of the alimentary canal of the worm did not consist of blood or of blood corpuscles, it was supposed that the worms lived on the blood plasma, and further that the hæmorrhages which form around the point of attachment of the worm were only a small part of the loss of blood that occurred at these places.

The anæmia has all the characters of one due to a hæmolytic toxin. The red corpuscles are much reduced in number, there are deposits of hæmosiderin in the liver and kidneys, as in cases of progressive anæmia due to hæmolysis, and of iron in inorganic combination in these organs.

In the advanced cases of anæmia numerous worms may be present and yet the anæmia very slowly increases, although if the progress of the anæmia were due to numerous minute hæmorrhages it should become still more rapid in advanced anæmics.

In infection with *Bothriocephalus latus* a similar form of anæmia occurs, though there are no hæmorrhages at all. Looss has shown that in the ankylostoma there are cephalic glands, and it is suggested that these possibly secrete a toxic substance.

The general opinion now held is that a hæmolytic toxin formed by the worm in the intestinal canal of man is absorbed into the blood, and that this toxin whilst in the portal circulation causes hæmolysis of the red corpuscles.

The Parasites.—The two species of worms considered appear to have the same effect, and in their life-history also closely resemble each other, so that for symptomatology, etiology, and prophylaxis they are of similar importance.

Ankylostomum duodenale is found throughout Asia, India and China, in the South of Europe, and in the islands of the Pacific and Indian Oceans, as well as in Tropical and Subtropical America. In many of these countries it may have been introduced by labour from India.

Necator americanus was first described in America, but probably is the indigenous species in Tropical Africa. It is the worm found in the pigmies from the Central Forest, in Uganda and on the West Coast. In America it is common, and may have been introduced by the Negro slaves. Both worms are found in many places in Tropical America, as both Indian and Negro labour has been imported, and in the Malay States, Ceylon, and Assam. More information is required as to the species found in the aboriginal races in the Pacific Islands and in South America.

Life-history of the Worms.—The eggs are, when passed with the fæces, in the early stages of segmentation, and under favourable conditions rapidly develop, so that they frequently contain embryos in twenty-four to forty-eight hours. The main conditions required are moisture and heat. Sufficient moisture is always contained in the fæces, the temperature is therefore the main factor to be considered.

The optimum temperature is a uniform one of 75° F. Below 75° F. development is delayed, and progress is slow and incomplete. Near the freezing point many eggs die, but some survive and will hatch out when exposed to suitable conditions.

The embryos when hatched out are actively motile rhabditiform embryos. They live in fæces, decomposing or otherwise, for two or three days and rapidly increase in size. If kept in undiluted fæces they do not continue to develop and soon die. In moist earth they live for prolonged periods, months or even years, and continue to develop up to a definite stage. In their final stage of development in this, the free-living, form they are motionless and enclosed in a thick sheath formed by the discarded cuticle. In this condition they will live for months without undergoing further development.

Various observers have described the development of these embryos into free-living sexual forms, but all carefully conducted experiments where sterilized earth is used

and no *Strongyloides intestinalis* were present in the fæces have failed to demonstrate this mode of development. The experiments have been so numerous and so generally unsuccessful that the existence of a free-living sexual form may be excluded.

The fully developed embryos are found in moist earth and in mud. They remain alive in water, but fall to the bottom of the water, and are not therefore likely to be taken up with drinking water.

Infection of man occurs if the embryos are swallowed. This probably happens most frequently from eating, or mixing food with fingers soiled with earth containing ankylostome larvæ.

Looss has shown that there is another method by which infection takes place. He finds that the larvæ can penetrate into the skin and through it, and in the case of the allied parasites of dogs, *Uncinaria trigonocephala*, he demonstrated the subsequent passage of the larvæ into the vessels and that they were carried in the blood to the lungs. From the lungs they pass into the trachea and down the œsophagus into the stomach. When the larvæ have reached this stage they are not destroyed by the acid contents of the stomach and pass on into the duodenum, where they undergo ecdysis and attach themselves to the mucous membrane of the small intestine. Looss has shown that the infection of man can take place in a similar manner and the worms reach the intestine. A certain amount of irritation of the skin is caused by the entrance of these larvæ, and it is suggested that the vesicular eruptions on the feet and elsewhere—"water itch" (not "coolie itch")—are due to the entrance of these larvæ.

Looss has further shown that the ankylostome larvæ are soon killed by the addition of water acidified with 0·2 per cent. hydrochloric acid, which he takes as the normal acidity of the contents of the human stomach.

The acidity of the stomach may average 0·2 per cent. during active digestion of proteid food, but it is below this in persons not in good health, and often much below.

In some common forms of dyspepsia it never reaches this degree of acidity. When water is taken alone little or no acid is secreted in the stomach and the water does not remain long in that viscus. With a purely vegetable diet little acid is formed. The argument as to the 0·2 per cent. acid is not conclusive as excluding the possibility of living larvæ passing through the stomach at some time or other even in healthy persons.

Whether or not infection by the mouth is the commonest method of infection to be considered may be doubted. There are some etiological factors in favour of the view that this is the important and ordinary method in which large infections are acquired. The incidence of the disease amongst the different races working on the same land varies greatly, though both are doing the same class of work, and both work barefooted. The one race, such as the Indians, eat rice mixed by hand and finely divided, so that there are great possibilities of such food being contaminated with particles of earth on the unwashed hands. Another race, such as the Fijians, or Melanesians, though holding the food in their hands, eat solid masses of food, such as the cooked tubers of yam or of the *Arum esculatum*, and in these solid masses, where the outside only can be contaminated, the chances of the introduction of ankylostome larvæ are distinctly less. Members of such groups may harbour a few ankylostomes, large numbers are but rarely present. "Water itch" is common in many districts where ankylostomiasis is rare, and rarely seen in others where it is prevalent.

Prophylaxis.—As the recognition of the eggs is a simple matter it is important that in any district where the infection is prevalent the general public should be properly instructed as to the causation of the infection and its effects. With a, naturally, intelligent population much can be done at schools and by public lectures and demonstrations, and Rockefeller's Commission in the Southern States of America has proved the value of

enlisting the services and sympathies of the classes infected and awakening the interest of all classes in the prevention of this preventable disease. The detailed methods would differ if it were proved that the usual method of infection was through the skin of the legs. If that were the case, the plan of making all labourers dip their feet and legs in Barbados pitch or some other substance that would adhere to the skin and deter the larvæ from penetrating it would be sufficient. The use of boots no doubt would protect, but for coolie labour would be impracticable. In mines where the hands are likely to be soiled these also would have to be protected. If introduced with the food the prevention of any chance of introduction of particles of earth into the food after cooking, and thorough washing of the hands before partaking of food, should prevent infection. The rational prophylaxis applicable, whatever the manner in which the larvæ enter man, consists in so disposing of the human excrement that the eggs or young larvæ are destroyed before they have any opportunity of entering man.

The conditions under which infection is most certain are those in which defæcation is allowed to take place broadcast on the surface of the earth. Even in a dry climate the amount of moisture in the fæces is sufficient both to allow the larvæ to live, and also to sufficiently moisten the earth underneath for the larvæ to escape into it.

In cane-fields and mines where there is always abundant moist earth or mud the conditions are still more favourable to the larvæ, as in this moist earth the larvæ develop to a certain extent and may remain alive for months.

Unregulated, superficial deposition of human fæces must be prevented or ankylostomiasis will be prevalent, wherever the temperature of the ground is sufficiently high.

Deposition of excrement in shallow cesspits is preferable. In some places larvæ of certain Muscidæ (Sarcophagidæ) are rapidly deposited on the fæces, as living larvæ. Where these larvæ are numerous, as they are in open cesspits in many places, any fresh fæces are at once

invaded by them. The eggs of ankylostomes and young larvæ are destroyed in the course of their passage through the intestines of these dipterous larvæ. For this to take place the muscid larvæ must be of species that will live in the contents of a cesspit till ready to pupate. Young muscid larvæ do not feed sufficiently voraciously, and the larvæ of flies like *Musca domestica* that soon leave the fæces are of little value. In other cases, where the cesspits are merely holes in the earth, and there are no or few dipterous larvæ, the ankylostome larvæ pass into the earth, so that the soil of the neighbourhood of the cesspits becomes infective. This is preferable to the widespread infection that takes place where defæcation is diffuse. In brick, cement, or other impervious cesspits, the decomposing fæces do not form a suitable medium for the development of the larvæ and they soon die. In a septic tank they are rapidly killed. In the manufacture of poudrette the eggs and larvæ of ankylostomes are completely destroyed, both when the powder is made by air drying on an impermeable floor or by the application of artificial heat.

The prevention of the spread of ankylostomiasis can therefore be effected by many methods of disposal of sewage. The dangerous methods are deposition on the surface of the ground, superficial burial, and even shallow trenching whilst the fæces are fresh.

In mines a good deal depends on the degree of acidity of the water in the mines. In the Transvaal, according to Turner, though the acidity varies, according to depth, age, &c., there is usually a considerable degree of acidity due to sulphuric acid from decomposing pyrites. An acidity of over 0·1 per cent. sulphuric acid will prevent the formation of larvæ, and this is exceeded in some of the mines. Boycott has also shown that 2·5 per cent. of salt solution rapidly destroys larvæ.

Triodontophorus.—Small sclerotomes first found in equines in Egypt and subsequently in the gorilla. In man a species, *Triodontophorus deminutus*, was found in

the intestine of an African Negro from Mayotte, and more recently by Turner in several natives of Nyasaland.

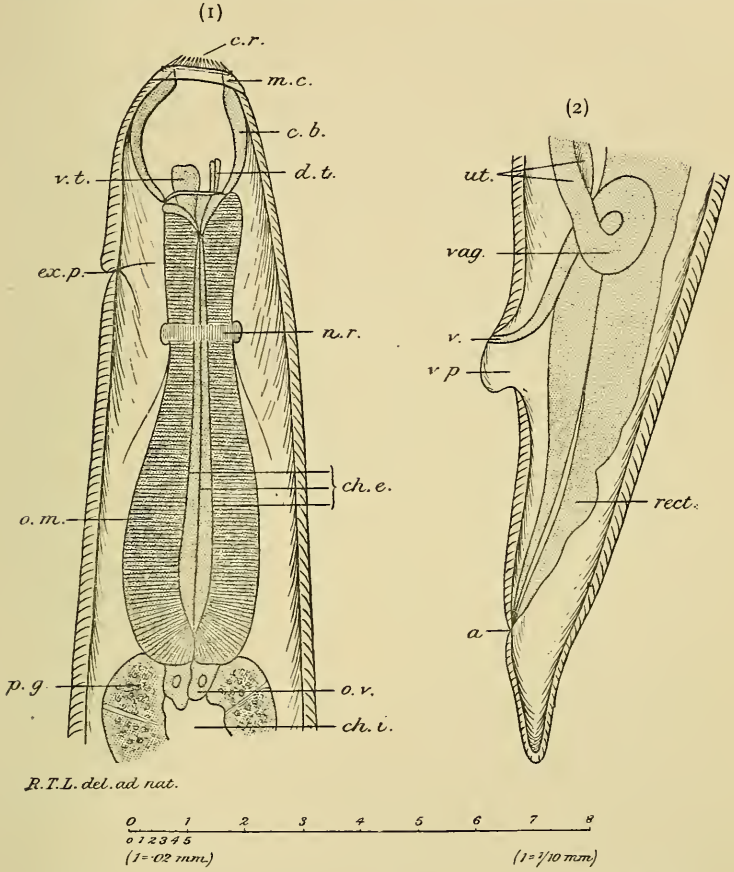


FIG. 65.—(1) Anterior end of *Triodontophorus deminutus*, Raill. and H., lateral view. *c.r.*, corona radiata; *m.c.*, mouth collar; *c.b.*, buccal capsule; *d.t.*, dorsal tooth; *v.t.*, ventral tooth; *ex.p.*, excretory pore: *n.r.*, nerve ring; *ch.e.*, chitinous edges; *o.m.*, œsophageal muscle; *p.g.*, pigment granules; *o.v.*, œsophageal valve; *ch.i.*, chyle intestine. (2) Posterior extremity of female *T. deminutus*, lateral view (Leiper). *ut.*, uterus; *vag.*, vagina; *v.*, vulva; *v.p.*, vulval pad; *rect.*, rectum; *a.*, anus.

The worms are about the size and general form of female ankylostomes, but are straight and not bent at the head end. The Nyasa specimens were 14 to 16 mm. by ·73 mm.

The opening of the buccal capsule is surrounded by two delicate cuticular fringes—the corona radiata ; these fringes are composed of twenty-four pieces. The buccal capsule is elongated, the dorsal portion being slightly shorter than the ventral. The œsophagus is stout and muscular, and triradiate in section. Each of the three surfaces is prolonged upwards into a chitinous plate projecting into the buccal capsule. The free terminations of these plates form the three teeth which guard the œsophageal opening. The anus is subterminal. The genital opening in the female opens posteriorly. It is twice as far from the anus as that is from the pointed tip of the tail.

These worms are blood-suckers, they are intestinal parasites, and in Turner's case were found in the large intestine.

Œsophagostomum brumpti.—Round the anterior extremity of the worm is a transparent cuticular thickening, surrounding the opening of the alimentary canal and armed with chitinous plates. The buccal cavity is not dilated, the mouth opens into the œsophagus, and the orifice of the œsophagus is armed with three teeth. It is parasitic in pigs and mammalia. In man it was found by Brumpt in cysts in the wall of the large intestine. The specimens were immature females and have been described as *Œsophagostomum brumpti.*

Other Œsophagostoma have been found in small, raised, rounded tumours mainly in the lower part of the ileum, but also occurring in the cæcum and colon. They bulge into the lumen, but are situated beneath the mucosa and sometimes beneath the muscular layer. The worms are found singly in the interior of these tumours in the semi-liquid contents of the cysts, which may be brownish in colour.

The worms are often immature. In Thomas's case the males were 17 to 22 mm. in length by ·75 mm. in breadth. Caudal pouch with thick ribs. Females 16 to 20 mm. in length ; immature forms only ·9 mm. in breadth.

Possibly the encysted "ankylostomes" mentioned by several observers in various parts of the Tropics, including British Guiana, were Œsophagostoma, and in that case

infections with these worms are more common than is at present believed.

This worm is closely allied to the forms that occur in the chimpanzee and gorilla.

Syngamus. — Mouth large and terminal and leading into a dilated buccal capsule; at the bottom of the capsule surrounding the orifice of the œsophagus are six sharp chitinous teeth. Copulation is permanent, males and females being found firmly adherent to each other. The male has two equal spicules, and the caudal bursa is supported by numerous ribs. Parasitic mainly in the laryngeal passages of ducks, fowls, and sometimes found in mammals, and common in calves of the Indian water buffalo in the Malay Peninsula. In man specimens have been found in the sputum of a native of St. Lucia by Dr. King. This isolated observation renders it probable that some species, probably mammalian rather than avian, is at times an accidental parasite of man.

CHAPTER XIV.

ASCARIDÆ

Ascaridæ.—The mouth is surrounded by three prominent lips, one dorsal and two ventral. The cloaca in the male is subterminal, there is no copulatory bursa, there are two equal spicules, and numerous pre-anal and post-anal papillæ.

In the female there are two ovaries, and the genital opening is anterior to the middle of the body. The Ascaridæ include a large number of species parasitic in birds, mammals and reptiles. The important species in man is the *Ascaris lumbricoides.*

Ascaris lumbricoides (*"Round-worm"*) is found in the small intestine, but may wander into the stomach and be vomited, or pass into the large intestine and be expelled with the motions. The male is 15 to 25 cm. by 3 mm. in breadth. The tail is strongly curved ventrally. There are two spicules, seventy to seventy-five papillæ; seven of these are post-anal.

The female is 20 to 40 cm. by 5 mm. in breadth. The tail is straight and the anus is close to it. The uterine tubes are much convoluted and are ten to fifteen times the length of the worm. The opening of the vagina is at the junction of the anterior third of the body and the middle third.

The three prominent lips characteristic of the genus are well marked. The dorsal lip carries two sensory papillæ, the two ventral lips each have one.

The common round-worm of man is the *Ascaris lumbricoides,* which occurs in all countries, but in the temperate regions is most commonly found in

children, whilst in the Tropics it occurs at all ages and sometimes in enormous numbers. This well-known worm varies in colour, but is usually grey or partly reddish.

Though the worms may be passed *per os* or *per rectum* the diagnosis is usually made by examination of the stool for ova. The ova vary greatly in appearance as they are seen in the stools. This variation depends in part on an albuminous covering which varies in thickness. The colour is brownish-yellow, as it is stained by the colouring matter in the fæces. The contents of the egg vary, as some eggs are not fecundated.

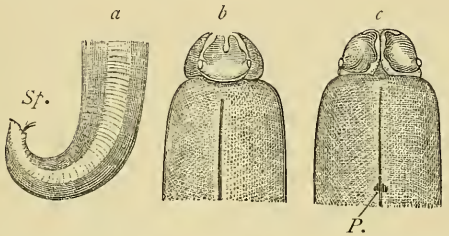


FIG. 66.—*Ascaris lumbricoides*. *a*, posterior extremity of the male with the spicules protruding from the orifice of the cloaca (*Sp.*); *b*, anterior extremity from the dorsal surface; *c*, anterior extremity from the ventral surface; *P.*, porus excretorius. (From Claus.)

The egg varies in shape; it is usually elliptical but sometimes nearly spherical. It is composed of a thick transparent shell which is not stained by the fæces and encloses the unsegmented ovum which does not completely fill the shell. When the egg is not fecundated the contents contain numerous refractile globules, probably unabsorbed food material, and may then appear to be composed of numerous unequal segments.

In the great majority of cases the egg-shell is covered with an albuminous coating which is rough and irregular on its outer surface and brownish in colour. It may be absent or in some cases easily detached. In the preparation for microscopic examination the albuminous coating is often detached in part or altogether, especially if the

preparations are roughly made. The eggs are very resistant. If kept moist the embryo slowly develops, at a medium temperature, in about thirty to forty days, but may remain alive for years, and if such eggs are ingested by man the embryos are set free and become larvæ which reach maturity in about five weeks.

Serious trouble may result from the wanderings of these worms. They may travel up the bile-duct, and reach the gall-bladder or biliary ducts in the liver, and have been known to cause hepatic abscess. They also appear to aid in the perforation of ulcers and to bore into adhesions between the intestine and other organs, and set up abscess or peritonitis. In some such manner they occasionally reach the urinary system and may be expelled with the urine. In children the abdomen becomes flabby and is protuberant, there is often persistent stomach-ache, perversion of appetite, and there may be picking of the nose and frequent attacks of night terrors.

A person may harbour ascarides and be in perfect health, but if very numerous, or if they occur in debilitated persons, they cause a certain amount of anæmia and dyspepsia, and have been credited with causing cerebral symptoms. In chronic dysentery the expulsion of worms is so often associated with rapid recovery or improvement that it is not advisable to consider them as harmless. It is a safe rule to expel these worms when their presence has been ascertained.

Diagnosis can be readily made by examination of the fæces for eggs.

Treatment.—Thymol, eucalyptus oil, β-naphthol, &c., may expel these worms, but santonin gives the best results, and where no other eggs are found should be always used. This may be given in capsules or dissolved in castor-oil. Four to six grains in an ounce of oleum ricini for children; some prefer 1-grain doses each of santonin and hydrargyrum with creta twice a day for two or three days.

As a rule the worms are easily expelled, but a patient

must never be considered to be completely relieved until the stools have been found to be persistently free from the eggs.

Ascaris canis or *mystax* is a common parasite of cats and dogs, and may be found in man. It is a much smaller worm than *A. lumbricoides;* the males are 40 mm. to 60 mm. in length, and the females one-quarter larger.

On each side of the anterior extremity the cuticle is expanded into broad longitudinal ridges—the alar appendages. Those infesting dogs and cats are distinct species, as the shape of the alar appendage varies. Leiper considers that the differences are sufficiently great to consider them as belonging to different genera. That of the cat he names *Belascaris mystax*, whilst that of the dog, in which the alæ are longer and divided by a depression into two lobes, he calls *Toxascaris limbata*. Both forms have been observed in man.

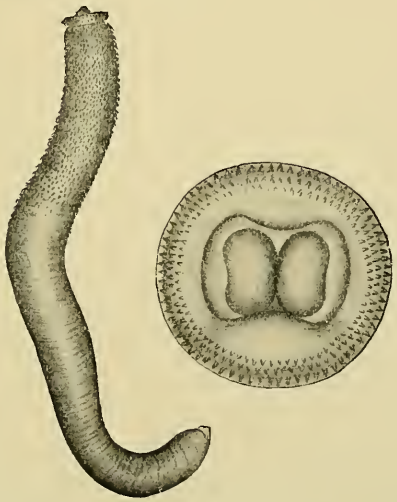


FIG. 67.—*Gnathostoma siamense*. To the left, the entire worm, enlarged; to the right, the head seen from above, much enlarged. (After Levinsen.)

GNATHOSTOMIDÆ.

Gnathostomidæ.—Most of the members of this group are intestinal parasites. They are short worms with a

somewhat broad or globular anterior extremity. The oral opening is guarded by two prominent lips, and the body in its anterior half is covered with spinous processes pointing backwards. Four glands are arranged around the muscular œsophagus and each pair open by a single duct in the adjacent labium.

Gnathostoma siamense (fig 67).—The human species is found only in Siam, and is not a very rare parasite there. It has been found only in subcutaneous tumours, and the worms have been immature. Eight rows of bristles surround the head. The females are 9 mm. by 1 mm. in breadth. The only male discovered was 5·10 mm. in length by 0·6 mm. in breadth. The male has two unequal spicules. The cloaca is subterminal, and there are two pairs of pre-anal and two pairs of post-anal papillæ. Probably these worms are accidental parasites of man. They are found in the tiger, dogs and cats.

Physaloptera.

Physaloptera have two greatly developed lips, each with two papillæ externally, a sharp tooth on the summit of the lip, and internally a tooth. There is a cuticular collar surrounding the mouth parts. The caudal pouch of the male—copulatory bursa—is closed and surrounds the tail. There is a series of papillæ, usually ten, on this bursa. The vagina opens in the anterior half of the body. The eggs have a thick, smooth outline. Usually parasitic in the intestines of birds. Physaloptera have been found as intestinal parasites in man in East and South Africa, and are described as *Physaloptera mordens.*

Physaloptera mordens.—These worms could easily be mistaken for immature round worms. The males are up to 50 mm. in length, and the females 55 mm. They are 2 to 3 mm. in breadth. The body tapers slightly anteriorly, and posteriorly more rapidly, terminating in the female in a sharp point.

Oxyuris

Oxyuris (Oxyurias).—The three labial prominences are slightly marked. The œsophagus has a marked double dilatation. There is a single spicule in the male and two pairs of pre-anal papillæ. The opening of the vagina is anterior, and the end of the female is drawn out to a sharp point.

Oxyuris vermicularis ("Thread-worm") is the only representative in man. It occurs in temperate and tropical climates, and causes more trouble in children than in adults. Probably it is more common in adults in the Tropics than in temperate climates.

The female is a white worm, about 10 mm. in length and 0·6 mm. in breadth. The male is shorter, only 5 mm., and can readily be distinguished as the tail is not pointed and is curved on itself (fig. 68).

The life-history is interesting. The worms, male and female, are found in the small intestine, where copulation occurs. The females only travel downwards and accumulate in large numbers in the cæcum, vermiform appendix, and ascending colon. When the eggs are nearly mature the females again travel downwards towards the rectum. They rarely pass any eggs in the large intestine, but pass out at the anus, and stimulated by the cold air the uterine tubes contract and the eggs are expelled and deposited round the anus and on the skin in the perineum. Mature females containing eggs are often passed with the fæces. Eggs are only found in the fæces exceptionally.

A considerable, sometimes intolerable, itching of the perineum is set up by the wanderings of the worms or from irritation caused by the eggs, or possibly by larvæ which escape from them.

The eggs, when passed, contain a fully developed embryo. The egg-capsule, though thin, is a little thicker and much tougher than in the ankylostome egg, which it resembles in size, though in shape, as well as in the development of the egg contents, it differs, as the eggs are flattened on one side.

Development is simple. The itching and irritation caused by the worms round the anus, especially at night,

FIG. 68. — *A*, male, and *B*, female, of *Oxyuris vermicularis*. 5/1.

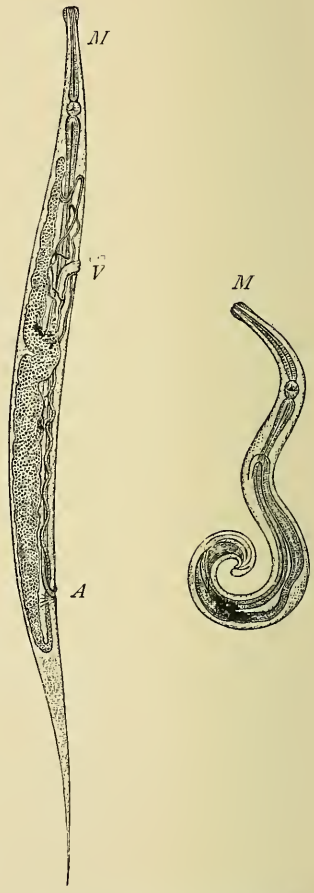


FIG. 69.—On the left, female; on the right, male; greatly enlarged. *A*, anus; *M*, mouth; *V*, vulva. (After Claus.)

leads to scratching or rubbing of that region. The eggs are then transferred to the fingers; from these they are transferred to the mouth or nose, and so reintroduced

into man. The egg-capsule is dissolved off or bursts in the stomach, and the embryos become sexually mature in about fourteen days.

Infection from man to man takes place if the eggs are transferred by hand, directly or indirectly. In crowded institutions, especially amongst children, general infection can readily take place.

The local irritation is the main trouble in most cases, and in many of these it is sufficiently severe to cause insomnia. In other cases reflex symptoms are set up in children, often causing nocturnal micturition and predisposing to masturbation, particularly amongst girls, and in rare cases are said to induce epileptiform convulsions.

Treatment.—The chronicity of the infections is due to the frequent reinfections. Large enemata of infusion of quassia and other substances will lead to the passage of the mature and the nearly mature worms which are in the sigmoid flexure. This, preceded by free purgation, will give rest for a week or two; and if the process is repeated at intervals of three or four days several times, all the worms will be passed without any eggs being deposited on the perineum. In any case, the perineum and the margin of the anus should be smeared with mercurial ointment. This either prevents the adults depositing the eggs, or kills off the eggs and also allays the irritation.

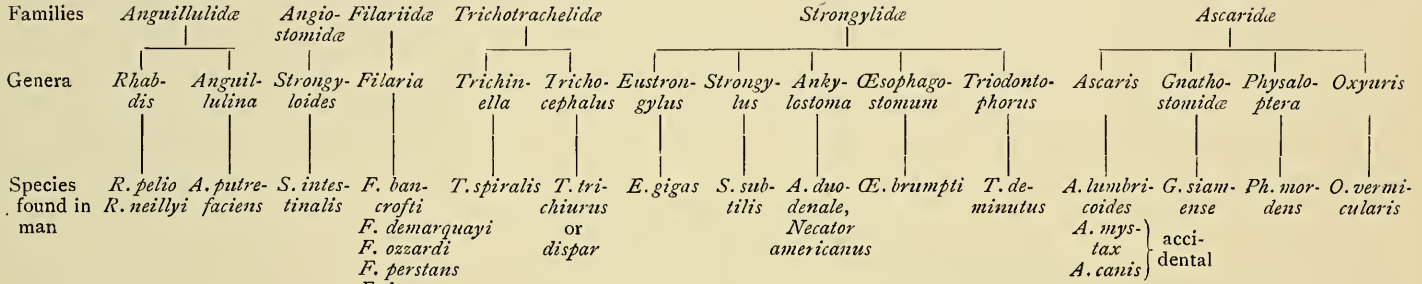
Treatment by the mouth with eucalyptus oil, chloroform, and ol. ricini, as for ankylostomes, causes the evacuation of immature as well as of mature worms in very large numbers. This method, combined with local application of mercurial ointment, is the most satisfactory, but in children the doses must be small.

Acanthocephala.

Acanthocephala.—Elongated round worms with a protrusible proboscis thickly covered with hooks. No mouth or alimentary canal. The sexes are separate, and the sexual organs are well developed. In the male there are

NEMATHELMINTHS.

Nematoda Parasitic in Man.



two testes, and the ducts from these unite in a single ejaculatory duct which is usually furnished with six or eight glands, and opens into a penis at the bottom of a protrusible bursa.

In the female there is a single ovary. The eggs are passed into the body cavity, where they become mature, the embryos develop and are surrounded by a capsule before they are extruded from the genital opening which is posterior.

The genus *Echinorhynchus* is represented by numerous species parasitic in the intestines of birds. Some of these species are two or three inches in length, and may be somewhat flattened and wrinkled transversely. On a casual examination they may be mistaken for tapeworms. Other species are short, smooth and hard, and may be mistaken for seeds.

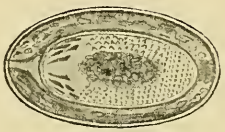


FIG. 70.—Egg of *Echinorhynchus gigas*. 300/1. (After Leuckart.)

They are sometimes found in mammals, and one species, *Echinorhynchus gigas*, has been found in man. The condition will probably not be diagnosed unless the characteristic eggs (fig. 70) are found in the fæces. It is a common parasite in the intestines of pigs. The intermediate hosts are various species of beetles.

DIAGNOSIS OF ENTOZOA.

Diagnosis of Entozoal Infections. — Portions of tapeworms—ripe proglottides—are passed with the fæces and can be readily diagnosed.

Oxyuris vermicularis, when fully mature, are passed with the fæces, and may also be found on the perineum. No other worms are constantly passed as adults, though *Ascaris lumbricoides* in a small proportion of the cases will be passed either by anus or mouth.

Most of the other intestinal parasites are only passed after the use of powerful anthelmintics—thymol, santonin, oil of male fern, eucalyptol and chloroform, and the like—or occasionally as a result of brisk purgation.

For these worms the best method of diagnosis is the microscopic examination of the fæces for eggs or embryos.

This examination is a simple one. A portion of the fæces is placed on a slide and covered with a cover-glass of medium thickness, and the fæces "squashed" out into a thin enough layer to be transparent. If the fæces are too hard to be compressed a little water may be added, but if possible this should be avoided. If the motion is a fluid one it should be allowed to stand, and a portion of the deposit taken up with a pipette, as the eggs sink. Where measurements are essential the method of compression must be avoided, as eggs are easily distorted.

Most of the eggs found in human fæces are readily recognized. The oncospheres of the tapeworms are recognized by the thick, radially striated embryonic capsule, and the embryo with six hooklets in the interior.

The eggs of the Bothriocephaloidea, Fasciolidæ and Paramphistomidæ all have a capsule with an operculum and lid. The contents are yolk-masses and the undeveloped ovum. Most of the egg-capsules are coloured yellow or brown, but those of *Bothriocephalus latus* are nearly colourless. To differentiate between the eggs of different flukes measurements are required.

Eggs of the Schistosomidæ contain a fully developed miracidium. In *Schistosomum hæmatobium* the egg-capsule has a terminal spine; in *S. mansoni* the spine is lateral, and in *S. japonica* there is a one-sided thickening surmounted by a small knob representing the "spine."

With the Nematode eggs there is great variation. The characters of the capsule and of the egg-contents render discrimination possible.

In *Ascaris lumbricoides* the egg-capsule is thick and usually coated over with albuminoid material stained

yellow or brown. The egg is variable in size and shape, sometimes nearly spherical, at others markedly oval. The egg-contents are an undivided mass of protoplasm, but in unfertilized eggs there are numerous refractile globules throughout the egg-contents.

Trichocephalus dispar is a barrel-shaped egg of a yellow-brown colour. There is an opening plugged with mucus at each end. The egg-contents are an undivided mass of protoplasm.

The eggs of *Ankylostomum duodenale* and *Necator americanus* have a very thin transparent capsule. The egg-contents have already commenced to develop, so that they are divided into two or four masses of protoplasm, and if the fæces have been kept may be divided into eight or more masses, and if kept twenty-four hours some of the eggs will contain worm-like embryos. Careful measurements of uncompressed eggs are required to differentiate between the eggs of these worms.

The *Oxyuris vermicularis* rarely passes eggs before leaving the intestine. These eggs have a thicker transparent capsule than the ankylostome; usually one side of the egg is flattened, and at the time the fæces are passed the contents of the egg have developed into a vermiform embryo.

Strongyloides intestinalis is recognized by the free embryos which are passed, not by eggs. These embryos are in active movement and in a slide of semi-fluid or pasty consistence clear tracks are left wherever the embryos have wandered, so that even in small infections the embryos can readily be tracked. No other living embryos are found in the freshly passed stool, but in a motion that has been kept for twenty-four hours or more they might be confused with larval ankylostomes, which are much the same size. They can be distinguished from each other by the œsophagus, which in the ankylostome larvæ has a definite globular dilation close to the mouth, which is not present in that of *S. intestinalis*.

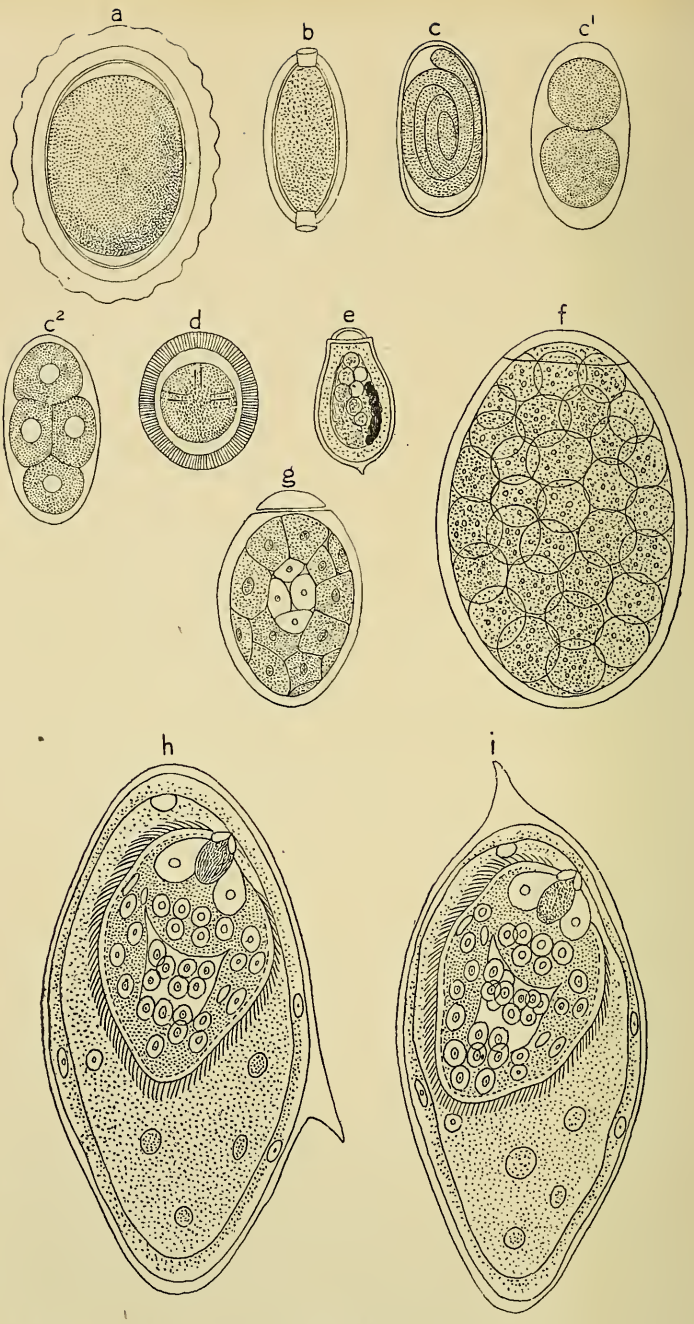


FIG. 71.—*a*, *Ascaris lumbricoides*; *b*, *Trichocephalus dispar*; *c*, *Oxyuris vermicularis*; c^1, c^2, *Ankylostomum duodenale*; *d*, oncosphere of *Cestode*; *e*, *f*, *g*, various *F. sciolidæ*; *h*, *Schistosomum* (?) *hæmatobium* (from fæces); *i*, *Schistosomum hæmatobium* (from urine).

MEASUREMENTS OF OVA.

T. saginata	0·03 to 0·04 mm. by 0·02 to 0·03 mm.
T. solium	(Spherical) 0·03 mm.
H. nana	,, 0·4 ,,
B. latus	0·068 to 0·071 mm. by 0·045 mm. (operculated).
F. hepatica	0·13 by 0·08 ,,
F. buski...	0·125 ,, 0·77 ,,
D. lanceatum	0·04 ,, 0·03 ,,
G. sinensis	0·027 ,, 0·016 ,,
H. heterophyes	0·03 ,, 0·017 ,,
P. westermani	0·08 to 0·1 ,, by 0·052 to 0·075 mm.
G. hominis	0·15 by 0·07 ,,
W. watsoni	0·12 ,, 0·075 ,,
S. hæmatobium	0·08 ,, 0·03 ,,
S. japonicum	0·06 to 0·09 ,, by 0·03 to 0·05 mm.
A. lumbricoides	0·05 ,, 0·07 ,, ,, 0·04 ,, 0·05 ,,
O. vermicularis... ...	0·05 by 0·016 ,, to 0·024 mm.
A. duodenale	0·056 to 0·061 ,, by 0·034 to 0·038 mm.
N. americanus	0·064 ,, 0.072 ,, ,, 0·036 mm.
T. dispar	0·05 ,, 0·054 ,, ,, 0·023 ,,

CHAPTER XV.

PROPHYLAXIS. *RÉSUMÉ.*

General Prophylaxis.—The life-history of each parasite has to be considered for economical and effective prophylaxis. There are many important gaps in our knowledge, particularly of the parasites with a complicated external life where intermediate hosts in all probability are essential. All Schistosomidæ are instances of this, and even as regards the Fasciolidæ and Paramphistomidæ parasitic in man a knowledge of the habits and species of the hosts would be an important aid in the prevention of infection. In considering the prevention of infection with parasites whose life-history in whole or part is known, we have to take into account:—

(1) How the parasite, eggs, embryos, or larvæ leave their host (man or other animals).

(2) What happens to them afterwards.

(3) How they re-enter their host (man).

(1) All parasites inhabiting the alimentary canal, the bile-ducts, and in some cases the vessels in the vicinity, leave man as eggs or larvæ in the fæces. These include TREMATODES, *e.g.*, *Fasciolopsis buski* and *F. rathouisi*, *Opisthorchis noverca*, *Clonorchis sinensis*, *Heterophyes heterophyes*, *Gastrodiscus hominis*, *Watsonius watsoni*, *Schistosomum japonicum*, *S. hæmatobium* (sometimes), and *S. mansoni*, as well as the Trematodes that are accidental parasites of man. All Cestodes except the Echinococcus. NEMATODES: *Ascaris lumbricoides*, *Trichocephalus dispar*, *Ankylostomum duodenale*, *Necator americanus*, *Oxyuris vermicularis*, *Strongyloides intestinalis;* as well as rarer Nematode parasites: *Strongylus subtilis*, *Triodontophorus deminutus*, *Physaloptera mordens*, &c.

Some parasites leave man by other excretions : *Schistosomum hæmatobium* usually in the urine, *Paragonimus westermani* in the expectoration.

The Filariidæ in most cases require the active intervention of a blood-sucking intermediate host, as in *Filaria bancrofti*, *F. loa*, and probably in the cases of *F. perstans*, and *F. demarquayi*, though the intermediate host in the latter cases is not determined.

Dracunculus medinensis is the only important parasite that itself provides for the discharge of its embryos by perforating the skin and discharging them directly into water. Possibly in *Filaria volvulus* the embryos find their way through the skin, but this is uncertain. Embryos have been found in some of the pustules in one of the many forms of pustular eruption popularly known as "kra kra" in West Africa, but whether these embryos were escaping through the skin, or what the parental form was, is unknown.

(2) *Changes outside the Human Host.*—The eggs or larvæ after leaving man always undergo further development. This development is a limited one, but may take a considerable time. When the limit is reached the embryos or larvæ may remain alive for indefinite periods without any further change taking place.

Where no immediate host is required the development is as follows :—

In *Ascaris lumbricoides* and *Trichocephalus dispar* the embryo forms inside the egg-capsule, but does not escape from it.

In *Ankylostomum duodenale* and *Necator americanus* the embryo escapes from the egg-capsule and continues to develop after leaving the fæces. Increases in size, living in damp earth or mud, and finally remains quiescent for prolonged periods enclosed in its last skin, which serves as a sheath.

In one method of infection by *A. duodenale* and *N. americanus* the embryo escapes from the sheath formed by the old integument and re-enters the definitive host

without any further change, perforating the skin of the host in order to do so.

In *Strongyloides intestinalis* the embryos have escaped from the egg-capsule before they leave man. After the fæces have been passed the larvæ in a few days become sexually mature, copulate, and produce rhabditiform larvæ, which at the first moult become filariform larvæ and are capable of becoming parasitic.

The Trematodes and Cestodes require for their development an intermediate host before they can attain sexual maturity in man. In many of them not only development, but an asexual multiplication, takes place in this intermediate host.

In the Trematodes, both Fasciolidæ and probably Paramphistomidæ require a mollusc or fish as the intermediate host. The eggs, having escaped, develop. The ciliated larvæ—the miracidium—having escaped from the egg has a short free life in water, and then entering the mollusc becomes a sporocyst in which several rediæ form, in each of which many cercariæ develop. These cercariæ are either deposited encysted on herbage or pass into water as free-swimming cercariæ, or enter another host which is subsequently devoured. We do not know what becomes of the miracidium in Schistosomidæ; probably they are capable of perforating the skin and do not require an intermediate host.

In the Cestodes either an embryo develops by the time the eggs are passed, as in the Tæniidæ, or it develops subsequently, as in the Dibothriocephaloidæ.

In either case the oncosphere, *i.e.*, embryo in its embryonic capsule, is swallowed by the intermediate host and the embryo, set free, passes into the muscle, liver, or other part of its intermediate host, becoming a cysticercus from which numerous scolices are produced—asexual multiplication—or only a few, or in some cases one only. In the Dibothriocephaloidæ the larva, having escaped from the oncosphere in the intermediate host, becomes an elongated larva—plerocercoid larva—no asexual multi-

plication taking place. The intermediate host according to the species of the worm may be mammals, sometimes man, arthropods, and in Bothriocephalus, fish.

(3) *Re-entrance into Man.*—The larvæ of *Filaria bancrofti* re-enter man, being discharged on to his skin by the intermediate host, the mosquito; and *Filaria loa* is transferred similarly by certain Chrysops. Probably other filariæ enter in a similar manner.

The larvæ of *Ankylostomum duodenale* and *Necator americanus* are capable of perforating the human skin, and so re-enter man. The same probably takes place with other nematode embryos, and it is possible that it is through the skin that the *Schistosomum hæmatobium* enters man.

Most of the worms with a simple development are reintroduced into man by the mouth with food, rarely with water. The eggs of the *Ascaris lumbricoides* and *Trichocephalus dispar*, containing the living larvæ, are widely scattered after the motions with which they were passed have disintegrated. These eggs in most instances probably are carried with dust. When swallowed the egg-capsule is dissolved off, and the embryos are set free and soon become sexually mature.

The filariform larvæ of the free-living generation of the Strongyloides are introduced by the mouth or penetrate through the skin, and in the intestine develop into the parasitic adult form.

Mature ankylostome larvæ are also introduced by the mouth. These parasites therefore may enter either through the skin or by the mouth, and probably the latter is in most tropical countries of the greater importance.

The cercariæ of the Trematodes probably always enter by the mouth, sometimes with water, but more frequently with vegetables, as they are deposited on them by the molluscs. Cestodes are introduced as cysticerci in food: Beef (*Cysticercus bovis*), the scolices developing into *Tænia saginata;* pork (*Cysticercus cellulosæ*), developing into *T. solium*. Of the other Tæniidæ some are introduced

probably through various insects, parts of them being accidentally swallowed.

The Bothriocephalus is introduced by swallowing imperfectly cooked fish containing the plerocercoid larvæ.

In the instances when man is the intermediate host, as when the *Cysticercus cellulosæ* develops in him or the *Echinococcus cysticercus* — hydatid cyst — he must have swallowed the oncospheres, probably with uncooked vegetables.

Trichina spiralis can only be introduced by swallowing imperfectly cooked and infected meat of various species of animals, usually pork—though flesh of man or rats would be equally effective.

Prevention.—The exact measures required for prevention in each worm must differ, but there are a few general problems involved.

It will be seen that verminous infection is rarely carried by drinking water, and even when it is so, as in the case of the Guinea-worm, the actual carriers, the Cyclops, are objects visible to the naked eye; or, as in the case of cercariæ of flukes, bodies sufficiently large to be removed by any rudimentary method of filtration. Though eggs and encysted larvæ may be found in the mud at the bottom of tanks they are not found in the superjacent water, as they are heavy and sink to the bottom. Water, therefore, that appears clear and free from visible parasites is not an important cause of verminous infection when drunk.

Bathing is more important, as in the mud at the edges and bottoms of pools or streams such worms as are able to penetrate the skin have every chance of doing so. Ponds, pools, and streams used for bathing are also often used for defæcation, many natives defæcating in water. Others defæcate in the luxurious vegetation often found at the edges of such watering places, and in either case the ground on the banks and at the edges will contain larvæ of ankylostomes, of Strongyloides, and possibly the supposed developmental forms of the Schisto-

somidæ (Bilharzia). Bathing, therefore, is a more real danger. Working in soil or mud is believed by some to be a fertile source of infection. Boots for Europeans form a sufficient protection. Natives, who cannot afford these luxuries, can be protected by walking through any of the liquid pitch combinations, such as Barbados tar.

As regards the larvæ, such as those of *Filaria bancrofti* and *F. loa*, which are injected by arthropods, protection from the infected insects is necessary.

In some cases the infection is conveyed by food contaminated carelessly with infected earth. Uncooked and insufficiently washed vegetables, badly cleaned utensils, and use of the fingers fouled with infected earth may also be sources of infection. The use of uncooked vegetables in any district where human excreta are used for manure should be abandoned, and other vegetables be thoroughly cooked.

Meats and fish must also be thoroughly cooked to destroy any larval cestodes, trematodes, or trichinæ. Imported foods, such as uncooked sausages, salted or partially cured meats, must be similarly treated before use.

Though much can be done to protect individuals, the protection of a community is a different matter, and should be dealt with by preventing, as far as possible, the dissemination of the eggs and larvæ of parasites. It is not only persons who are ill that harbour the parasites, many in good health have a few, and both classes distribute eggs and larvæ wherever they defæcate, and the fæces, the eggs and the embryos developed from them are washed into the water, or into the earth at the edge of it, or else they infect mosquitoes and biting flies wherever they go.

It is difficult to control the developmental stages passed outside the body. The thick-shelled eggs are very resistant. It is impossible to treat earth with antiseptics on a large scale, or to destroy snails, molluscs, or fish wholesale without the balance of life in such places being

disturbed and increase in other forms of life, possibly harmful, taking place. Something can be done by fumigation to destroy the domestic mosquitoes, possibly infected with filaria, during the fortnight or so required for the development of the larvæ.

The most hopeful measures are those that prevent the eggs being deposited in places suitable for their development. This involves a consideration of the natural means which aid in the destruction of such eggs ; and a modification of the present means adopted for disposal of fæces, when these are favourable for the propagation of intestinal worms. Wholesale treatment with anthelmintics of persons harbouring entozoal parasites is possible only where people are under constant observation and control, and the apparently healthy person who harbours parasites and distributes the eggs is very difficult to deal with. In mines, where this method has been adopted to some extent, it is found that many persons purge themselves thoroughly before the medical examination, and so, as the *eggs* are expelled, appear to be uninfected.

Native labourers usually dispose of their fæces by :—

(1) Deposition of fæces on cultivated lands or in natural bush—usually in the vicinity of water. The vicinity of water is important, because, not only is there more cover, as the vegetation is more abundant, but so many native races wash after defæcation. Under such circumstances, they stand in the water and mud in the vicinity of bush used as a latrine ground, so that infection, with ankylostomes, and probably schistosomes, is very liable to take place. The deposition of fæces on cultivated or moist earth affords the best possible chance for the development of eggs and larvæ.

(2) Deposition of fæces on dry earth or sand, as is common in the drier tropical countries. The fæces retain the moisture in the part in contact with earth, and the earth underneath is moistened, so that as the larvæ hatch out they can escape into the earth. Eggs with thick shells retain their vitality. Probably a much

smaller proportion of the eggs survive than in a moister country.

(3) Superficial burial. If very superficial, *i.e.*, merely covered with a thin layer of earth, there is little advantage over deposition on the surface as far as destruction of eggs is concerned. If in a trench, and that used by a considerable number of persons, during the decomposition of the fæces oxygen will be absorbed and some of the eggs and most of the larvæ killed from want of oxygen. In deep trenching probably few larvæ survive.

Deposition in Open Cesspits.—These, for the use of small gangs of men, fifty or so, are more convenient and more suitable than the previous methods. In any accumulation of excreta the deeper part is practically a septic tank—all the oxygen is absorbed. In the superficial layer muscid larvæ of the species that are capable of living in putrid fæces accumulate and rapidly invade and destroy any fresh deposits. Only the thick-shelled eggs survive their passage through the intestines of these larvæ, and these gradually sink into the anaerobic deeper contents of the pit and are slowly destroyed. If suitable muscid larvæ (Sarcophagidæ) are present, such a cesspit has very little smell, the fæces are rendered odourless and harmless very soon after they are deposited. The risks are bacterial contamination of water and the conveyance by flies of portions of excreta to food material.

Other Methods.—A well-managed septic tank built and managed on European methods is an effective way of dealing with eggs and larvæ of entozoa. Cement cesspits are also effective and can be rendered anaerobic by covering the surface of the deposits with a layer of oil. Ross's automatic oiler is suitable for this purpose (fig. 72).

The use of human excrement for manure is free from much risk if the dejecta have been kept sufficiently long and there is no admixture of fresh fæces. The Chinese store fæces and urine for some time before using them in large earthenware pots, but often it is mixed with fresh fæces and is then dangerous (fig. 73).

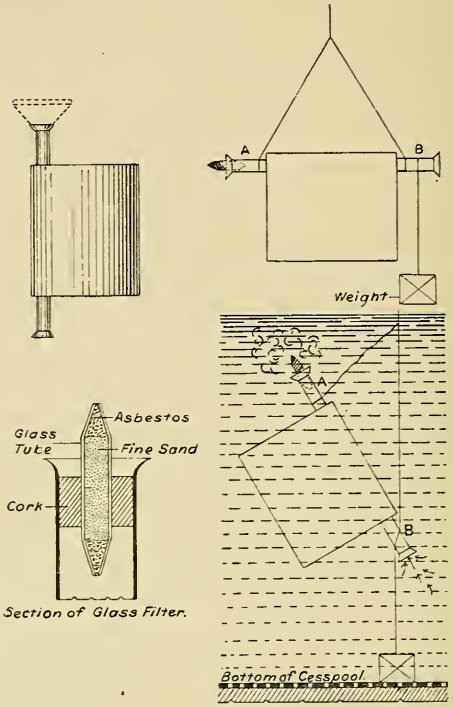


FIG. 72.—Ross's Automatic Oiler. The cylinder is filled with oil with a spout at each end. At A is a sand-filter blocking the spout and only allowing oil to exude slowly. This sand-filter is a glass tube drawn out at one end, and with a plug of glass wool in the cone so formed. The space above is filled with sand, a small plug of glass wool placed on it, and the glass tube above drawn out to a point.

A weight is attached to the spout B—a piece of galvanized wire attached to each spout and joined up above.

The cylinder is filled with oil through spout A and lowered horizontally into the cesspit till the weight touches the bottom. It is then lifted up by the wire attached to both spouts, and this is fixed to a nail.

The end B will be kept down by the weight, and as long as there is oil in the cylinder the end A will project upwards and oil slowly escape through the sand-filter. As the oil escapes and is replaced by water, the apparatus will become heavier and heavier, and at last sink and lie horizontally. When this happens there is a sudden gush of the residual oil, which indicates that the cylinder must be withdrawn by the wire and refilled, and replaced in about ten days.

A cylinder containing $3\frac{1}{2}$ litres of oil will require refilling in about ten weeks.

FIG. 73.—Disposal of Excrement as Manure. Chinese method.

(1) Chinaman taking from public latrines in a Government receptacle fresh human ordure.

(2) Decanting into his manure pit where, *if kept long enough*, the eggs of most entozoa will be destroyed. It is rarely kept long enough.

(3) Filling his private bucket with the contents of manure pit, consisting in part of fæces kept sufficiently long for eggs to be destroyed, but in part sufficiently fresh for eggs to retain their vitality. To the contents of this bucket water is usually added.

(4) Watering vegetables, including those used for salads or eaten raw, with the contents of this bucket. The great prevalence of "flukes" (Trematoda) amongst the Chinese is probably due to the general use of some such method.

The practice of some municipalities in allowing the pails from the public latrines to be taken away by private individuals, without exercising supervision to ensure that this material is not used, even in part, fresh, is not to be commended. Small gardeners (Chinese) usually have a single cesspit and the contents of the latrine pails are emptied into this, and the mixture of recent and old deposits is then used as manure, and the eggs and embryos distributed over the growing vegetables. The moderately resistant eggs, those of flukes, often survive this treatment.

Poudrette, the product of the desiccation and conversion into powder of the excrement mixed with ashes, contains neither larvæ nor ankylostome eggs, as these are destroyed in this process. Even the crude method of air-drying on a brick or cement floor and covering with ash is effective to that extent. The method is only suited for dry tropical climates.

The expensive and wasteful method of the destruction of excrement by incineration naturally destroys all eggs and larvæ. It is only suitable in dry climates and where there is abundant inflammable material to burn with it.

Addition of disinfectants in sufficient amount to destroy eggs is difficult, and the fæces so treated are injurious to land.

Deposition in the sea or in salt water effectually destroys eggs and larvæ. In deep fresh water the method is dangerous on account of pathogenic organisms often contained in the fæces. The eggs and larvæ in most instances will fall to the bottom, and being embedded in the mud are not so effective and are not likely to infect man.

The measures to be adopted must be those best suited to the local conditions. Amongst other things, the size of the settlement, the conservancy system in use, and the land available and its nature, have to be considered.

Cesspits are only permissible where surface wells are

not used and there is no chance of infection, with bacteria, of the water supply. Unless the right species of muscids, not *Musca domestica*, are present, they are very offensive.

Burial in trenches some 3 ft. deep and covering with 18 in. of earth is in most places the most suitable method. Public latrines must be provided for all gangs of labour and these must be sufficient to accommodate at one time at least one-sixth of the average strength. With inadequate latrine accommodation the most dangerous system of all—namely, defæcation in cultivated grounds or amongst the rank vegetation near water—is bound to occur. With adequate latrine accommodation and water for ablution purposes conveniently near, there is little difficulty in enforcing the use of these conveniences.

TABLE INDICATING BRIEFLY THE MODE OF INFECTION.

Worm	Leave man	Life outside man	Re-enter man
Ascaris lumbricoides *Trichocephalus dispar*	As eggs with undeveloped contents	Development of egg-contents into embryo in water or on earth	Eggs containing embryos are swallowed, usually with food.
Oxyuris vermicularis	Adults leave rectum and deposit eggs on skin	Eggs undergo little or no further development, as embryo is already formed	Eggs containing embryos are swallowed — usually reintroduced into the same patient.
Strongyloides intestinalis	Embryos passed with fæces	Develop, become sexually mature, and multiply sexually; the embryos so produced	Enter man with food, or in any substance contaminated with infected earth, or through the skin.
Ankylostoma duodenale *Necator americanus*	Eggs; division of egg contents has commenced	Embryos hatch out and develop to a considerable extent in moist earth	Embryos reintroduced by the mouth, probably in food contaminated with earth. Also enter through the unbroken skin.
Trichina spiralis	Embryos develop to their limit in the muscle of the host	Only in animal eating the infected flesh	Usually from eating pork containing encysted larvæ.

TABLE—*continued.*

Worm	Leave man	Life outside man	Re-enters man
Filaria bancrofti	Embryos abstracted with blood by mosquitoes	Embryos develop in mosquito into larvæ with alimentary canal	Larvæ discharged by mosquitoes on man and enter through the unbroken skin.
Filaria loa ...	By *Chrysops dimidiata*	Similar development in salivary glands of Chrysops	
Filaria medinensis	Embryos discharged into water	Embryos swallowed (?) by Cyclops and there develop to a certain extent	Cyclops containing developed larvæ swallowed by man.
See other filariæ	not known with certainty, probably to method	to *Filaria bancrofti*.	in some analogous
Tænia saginata...	Oncospheres	In muscle of cattle (*Cysticercus bovis*)	Eating beef containing *Cysticercus bovis*.
Tænia solium ...	Oncospheres	In muscle of pig (*Cysticercus cellulosæ*)	Eating pork containing *Cysticercus cellulosæ*.
Tænia echinococcus	"Hydatid cysts." Does not leave man, who is an accidental host	Adult worm in intestines of dogs, &c., who derive infection from food, offal from slaughter-houses, &c.	By swallowing oncospheres from fæces of infected dogs.
Trematodes, both *Fasciolidæ* and *Paramphistomidæ*	Eggs with undeveloped ovum in fæces, or, in one instance, in sputum	Ovum develops in water, embryo enters molluscs or fish, and there multiplies asexually, producing ultimately young flukes—cercariæ—either encysted on vegetables, or free swimming in water	Swallowed by man on vegetables or in water or in undercooked fish.
Schistosomidæ ...	Eggs with well-developed ciliated embryo — miracidium—with urine or fæces	Embryos escape from egg when urine or fæces diluted. Further development, if any outside man, unknown	Probably enters through the skin during bathing.

CHAPTER XVI.

LEECHES AND ARTHROPODS.

Hirudinea (*Leeches*).—A group of segmented worms allied to the *Chætopoda*. Very numerous species are known, but few of them attack man readily.

According to their habits they may be divided into two classes—those living in water and those living on land, usually in damp jungle country. Those living in water may not only attack externally, but if swallowed may fix themselves on the pharynx, nasal cavities, or œsophagus or trachea, and cause considerable trouble. To this group belongs the *Limnatis nilotica*.

Land leeches are prevalent in Asiatic jungle and rarely met with in American and African jungle. They may be very numerous, and are found on leaves, twigs, or elsewhere, awaiting an opportunity to attack some mammal. They are very active, and can pass through narrow orifices, such as the lace-holes of a boot, and will climb rapidly on the surface of, or between, clothes till they find an aperture. The bite is painless, and frequently the first thing noticed is that the boots are full of blood.

Beyond the loss of blood, which may be serious when many leeches have attacked a man, and the liability to bleeding from the bite, little trouble is caused. In some instances, and more commonly with some species of leeches than others, much inflammation, and even the formation of local sloughs, may occur. Some persons are much more liable to be attacked than others, and the liability to sloughing or irritation at the seat of the bite also varies in different people. The application of a solution of salt will usually cause the leeches to loosen

their hold. They should not be forcibly pulled off. In a badly infested jungle the clothes, boots, &c., should be damped with a salt solution. This usually serves as a sufficient protection, but may require renewal from time to time. Some persons, where sea water is available, walk through it with their clothes on prior to visiting the jungle; others urinate inside their clothes, a measure that is said to be efficient.

The best known species of leeches is the jungle leech of Ceylon, the *Hæmadipsa ceylonica*. In the Malay Peninsula several species are common.

Many parasites maintain their vitality for a considerable period in the stomach of leeches, but leeches are not known to act as carriers of disease.

Arthropoda.

Pentastomidæ are worm-like animals usually with numerous ring-like constrictions. These are not segments. There is a head which may, or may not, be separated by a neck. The mouth is median, and on each side is a row of hooks. There is a complete intestine ending in a terminal anus. They are bisexual, and the uterus opens externally in front of the anus. The male genital opening is behind the mouth.

There are no traces of legs in the adult forms, unless the hooks are these representations, but rudimentary legs, four in number, are found in the embryos. It is suggested that they may be degenerate vermiform acarina.

Two hosts appear to be necessary. The definitive hosts are usually snakes and a large number of species are now known. Birds are the definitive hosts of some species. The adult forms live in the lungs or nasal cavities. The eggs are discharged with nasal mucus and swallowed by a second host—mammal, bird, or fish. The larvæ are set free and travel into the tissues of the intermediate host, and escape only when the flesh is devoured. On the West Coast of Africa the *Pentastomum constrictum*, found in the liver in man, is the larval stage of a Porocephalus.

The adult is believed to be a Porocephalus which lives in snakes, pythons, in the lungs, possibly the *Porocephalus constrictus*.

Demodex folliculorum.—A nearly legless degenerate acarine which lives in the hair follicles and sebaceous glands of man and other animals. They are seen as black points around which there is a variable, frequently a negligible, amount of inflammation. They may, when numerous, cause a severe dermatitis. Such a dermatitis is more common in the lower animals. The small elevations surmounted by a black spot, so commonly found in man and termed comedones, often contain this parasite.

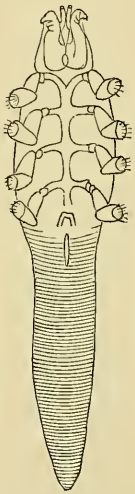


FIG. 74.—*Demodex folliculorum* of the dog. (After Mégnin.)

The females are 0·38 mm. in length and 0·045 mm. in breadth at the thorax. There is a rostrum, a fused cephalothorax with four pairs of legs which are very short, but composed of three joints. The abdomen is elongated, conical, and striated transversely. The anus is on the ventral surface (fig. 74). The males are smaller and the abdomen shorter.

This species is oviparous, and the eggs are fusiform in shape. The larva is hexapod, but the legs are only represented by tubercles. The nympha has four pairs of legs and is formed after the second moult. There is no evidence that this parasite is more common in the Tropics than elsewhere.

Scabies.—A pustular eruption similar in its characters, and due to apparently the same acarine, *Sarcoptes scabiei*, occurs in most tropical countries. It is not markedly more common than in temperate regions. The pustular skin eruptions known as coolie itch, itch, craw-craw, &c., are very common, bacterial as a rule, and due to various causes, but rarely to the *S. scabiei*. True itch, when it does occur, would no doubt be included in these popular designations.

Diptera.

Dipterous insects are injurious in many ways : (1) They may, as in the case of mosquitoes, be a necessary host of human parasites, *e.g.*, *Filaria bancrofti* and the parasites of malaria, or in the case of the Glossina be a host of *Trypanosome gambiense* or *T. rhodesiense*, or, as in *Chrysops dimidiata*, be the intermediate host of *Filaria loa*.

(2) They may be mechanical carriers—porters—of various bacilli.

(3) They or their larvæ may be directly injurious by penetrating the skin, inflicting wounds, or injecting poisonous venoms.

The dipterous insects capable of penetrating the skin and sucking blood are numerous. They include amongst the Nematocera many species of mosquitoes (Culicidæ), of Chironomidæ and Simulidæ—either of these when small are popularly know as "sand-flies"—Psychodidæ, owl midges, and amongst the Brachycera, the Tabanidæ, Tabanus, Chrysops, Hæmatopota, &c. Amongst the Muscidæ the various species of tsetse-fly (Glossina), Stomoxys, Hæmatobia, &c., and amongst Pupipara the Hippoboscidæ are biting flies and some are known carriers of disease.

These are of most importance as carriers of disease, either protozoal or verminous parasites, but also cause local irritation at and around the points where the puncture occurs. In newcomers this irritation may be severe, but after a time the effect produced is trivial. A degree of immunity is acquired. Even with newcomers the irritation soon passes off unless friction is employed; if the spots are rubbed the swelling and irritation increase, and is more persistent.

In certain places, particularly around the ankles and wrists, where bites are frequent, it is not uncommon to find that small abrasions which may lead to definite ulcers are produced. With some of the ticks and larval acarines, *e.g.*, "bête rouge," and other larval forms of Trombidiidæ, small local gangrenous patches are produced in some people.

The local application of strong ammonia, liq. ammon. fort., usually diminishes the irritation. Care must be taken not to rub the affected parts. This is more easily avoided if by the free use of pungent essential oils—oil of lavender and pennyroyal are the best—fresh bites in the neighbourhood of the old ones are prevented.

Suitable clothing is important, high "mosquito" boots give much protection, whilst hard, rough clothing such as some of the "cellular" underclothing should be avoided, as though cool and comfortable, friction with such substances readily produces a breach of the surface of the skin.

Prevention by the use of mosquito-proof rooms, nets and clothing should be adopted where possible. Even the colour of the clothing is of importance; black or dark stockings should not be worn by ladies, and low evening dresses are not advisable where mosquitoes are troublesome, though where good punkahs are used in well-lighted rooms the inconvenience is much reduced. Any powerful-smelling essential oil will for a time prevent attack, but only on and around the region of the skin or article of clothing to which it is applied. To many

persons the smell of these scents is almost more objectionable than the insect-bites. A mixture of several essential oils is more effective and less objectionable to many people than a single more powerful one. Colonel Alcock advocates the use of the following application to the skin as effective and not objectionable :—

Ol. bergamot	
Ol. cloves	
Ol. lavender	āā ℥ss.
Ol. terebinthinæ	... ℥ii.
Quininæ sulphate	... gr. xx.
Sp. vini rect.	... ℥viii.
Water	to 1 pint.

For mosquitoes the destruction of the nearer breeding places will, especially if the mosquitoes are Stegomyia, greatly diminish the trouble.

Myiasis.

Myiasis—Many flies deposit larvæ in wounds and ulcers in the skin or on mucous surfaces. Some deposit larvæ which are capable of penetrating the skin, and in others the larvæ are themselves blood-suckers. Larvæ are occasionally passed with the fæces. To all these affections the term Myiasis is applied. In some cases the larvæ do not actually invade the living tissues, but remain on the surface, and though causing irritation and increasing the area and extent of the wound, do not do the same damage as in the species whose larvæ live on the live tissues.

The larvæ may belong to several genera and to various species in each genus : *Sarcophagidæ*, several species, *Sarcophaga ruficornis* in India, *S. regularis* in Africa, and *S. chrysostoma* in America, are three of the more important which attack wounds ; *S. carnaria* has been found in the nose, conjunctivæ, anus, vagina, and in abscesses. *Sarcophila :* Some species deposit their living larvæ in wounds. *Lucilia* of several species have been found in wounds in man, whilst the *L. sericata* is the cause of "maggot" in sheep.

It is important to remember that even a properly covered wound or ulcer may become infected, especially by the flies that deposit living larvæ. The larvæ are small, and are deposited in the skin or dressings in the vicinity, and crawl under these dressings to the wound. It is no uncommon thing to find such larvæ crawling into a Petri dish, having been deposited outside by the adult, if the Petri dish contains an odorous substance or any decomposing or offensive animal material.

Dusting with calomel and treatment with lotio nigra are the most effective measures for getting rid of these larvæ, after picking out and syringing out as many as possible. If ulcers and wounds are kept clean, and the dressing changed so frequently that there is no odour, they are not likely to be invaded, as these flies are attracted by smell.

FIG. 75.—*Lucilia cæsar.*

NASAL MYIASIS.

In South America the most important and dangerous form of myiasis is that due to the *Chrysomyia* (*Compsomyia*) *macellaria*. This fly usually attacks some junction of skin and mucous membrane, and the larvæ then attack the mucous membrane. The most frequent place attacked is the nose, but they are found also in the orbit, the vagina,

penis, and rectum. The larvæ are popularly known as "screw-worms."

Wherever they occur they cause extensive destruction. The larvæ bury their heads in the tissue, which they destroy, and cause an extensive cellulitis. The depth and extent of their ravages are best seen in the orbit. The lids, muscles, and connective tissue are rapidly destroyed,

Fig. 76.—Effect of Nasal Myiasis.

whilst the eye, protected by the thick sclerotic, is not at first affected. In the nose they soon reach the nasal cartilages and bones, which are destroyed and the skin perforated. Whilst small they travel widely, so that they pass into the frontal and ethmoid sinuses, causing destruction and necrosis wherever they find their way, and death from meningitis is common. The condition is always a grave one, the mortality high, and in case of recovery there is usually much mutilation (fig. 76).

It is not certain if they attack perfectly healthy persons, though in some cases no history of antecedent nasal disease or discharge can be obtained. Usually there is some such history, and a large proportion of the cases are in lepers. The earlier the diagnosis is made the more successful is the treatment, and the less the damage done. The earliest symptom is some itching and irritation about the nares, with a certain amount of swelling of the nose and each side of it; the loose connective tissue beneath the lower lids being swollen early. The condition is often mistaken for facial erysipelas.

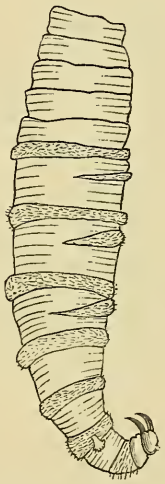


FIG. 77.—Larva of *Chrysomyia macellaria*. 4/1. (After Clonel.)

A larger species, *Chrysomyia viridula*, also acts in a similar manner.

In any case where there is spreading cellulitis round the nose, often shown first by marked swelling of the loose cellular tissue under the eyes, this condition should be suspected. Careful examination of the nares will often disclose the small larvæ. Thorough nasal irrigation may be necessary. Plugging the posterior nares, with subsequent irrigation, will usually bring away the larvæ,

A strong permanganate of potash lotion is often effective, but turpentine and water is more so. If the larvæ are removed early the irritation soon subsides. If the nature of the case is not recognized in some forty-eight hours or so, the cellulitis will have greatly increased, there will be a black discharge from the nostrils, the skin over the bridge of the nose perforated, and symptoms of general

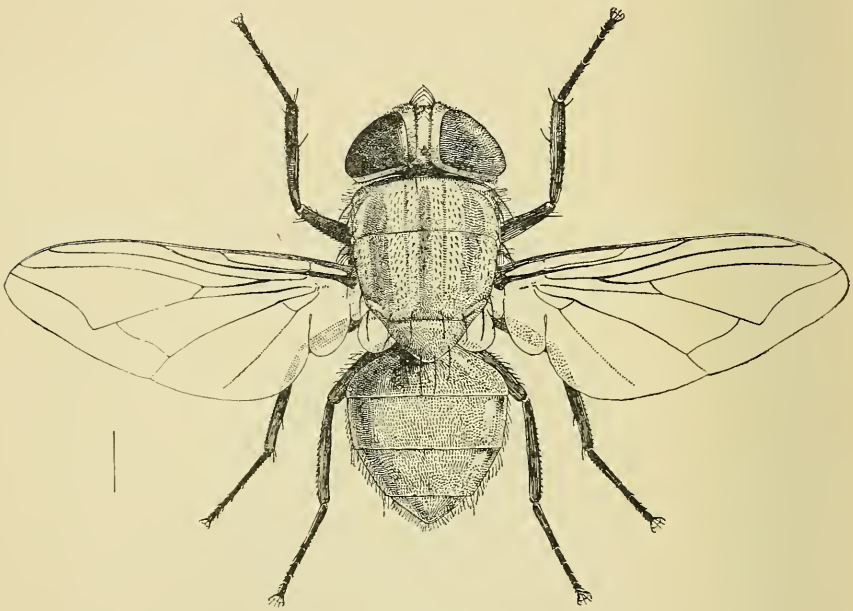


FIG. 78.—*Chrysomyia macellaria.*

septicæmia and possibly of meningitis. The larvæ will probably be seen readily, but as their heads are buried deep in the tissues are less readily removed. Treatment should be on the same lines in the hope that necrosis and suppuration in the ethmoid cells have not been set up. If the patient survives, in another forty-eight hours or so the larvæ, now fully mature, will escape naturally, as they do not pupate in their host. They escape by the nares as a rule, or through the perforation in the bridge of the

nose, if there be one, and travel rapidly to conceal themselves in any dark recess under the mattress, in the framework of the bedstead, in cracks in the floor or wall, or in any old clothing that may be lying near. A thorough and careful search should always be made for the larvæ and on subsequent days for the pupæ. They conceal themselves in such small crannies that some usually escape detection and a few freshly emerged imagines will generally be found in the vicinity of the bed (fig. 78) on the early morning of the ninth day after the escape of the larvæ in a tropical climate such as British Guiana.

The *Chrysomyia macellaria* is a fly that varies in colour from blue to green. It can easily be distinguished from Lucilia as there are broad black bands running lengthwise on the thorax (fig. 78). Badly kept hospital wards, such as those in an undermanned leper asylum, are very liable to become infected by previous cases, as the pupæ are not looked for and are allowed to hatch out, when they may reinfect other patients. In Asia, a fly—a *Pyonosoma*, sp. (?)—similarly attacks the nostrils, and may cause death. They are not so common as Chrysomyia are in Tropical America, and in appearance, without close investigation, resemble that insect. Some observations show that other flies may act in a similar manner, including Sarcophaga.

Intestinal Myiasis.

Intestinal myiasis occurs in temperate climates, as well as in tropical ones. Some of the cases reported are probably mistakes, as flies that deposit living larvæ do so so rapidly that they are deposited on the fæces as they are passed through the anus. Amongst the flies that so deposit larvæ are several species of Sarcophaga, and in some of the recorded cases of intestinal myiasis the larvæ were those of Sarcophaga.

Undoubted cases do occur in which well-developed larvæ are passed with the fæces. The larvæ are sometimes those of Anthomyidæ, *e.g. Anthomyia desjardensis.*

Homalomyia canicularis is one of the commonest of these causes of intestinal myiasis (figs. 79 and 80). It is generally believed that the eggs or larvæ are swallowed with raw vegetables and pass through the intestinal canal where

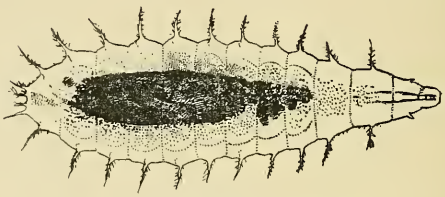


FIG. 79.—Larva of *Homalomyia.*

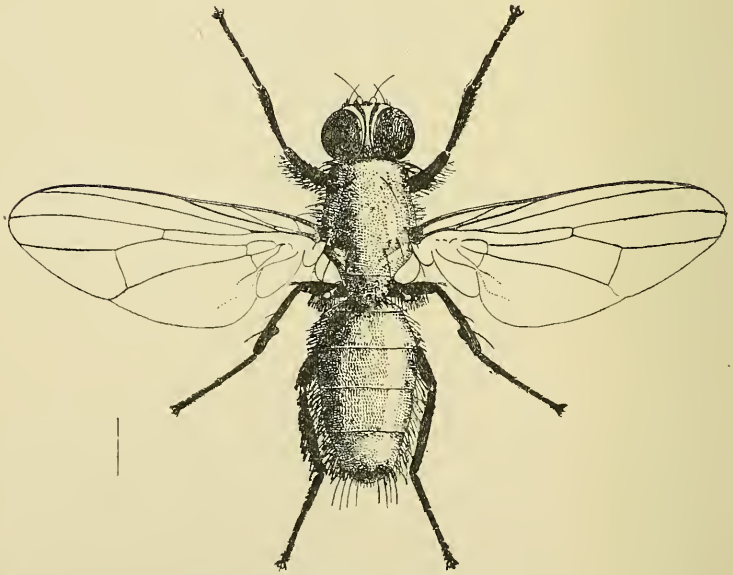


FIG. 80.—*Homalomyia canicularis.*

they undergo further development. This is almost certainly the case where the rat-tailed larvæ of *Eristalis tenax* or of the cheese-maggot fly, *Piophila casei*, are passed with the stools.

In Tropical Asia, a small fly, which is also found in South America—*Aphiocheata ferruginea*—is capable of living in the human intestine, and in one case reported by Baker newly hatched and full-grown larvæ were passed for a period of ten months, and also a few adult flies. During this period no food was taken that could

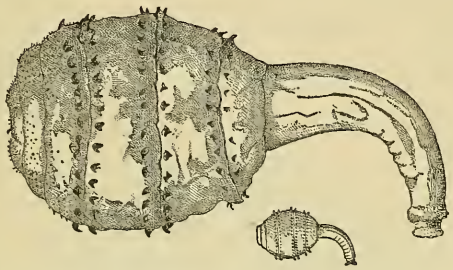


FIG. 81.—Larva of *Dermatobia cyaniventris* in its natural size and magnified. (After Blanchard.)

FIG. 82.—*Dermatobia noxialis*, Goudot.

have harboured eggs or larvæ. As other species of this family—*Phoridæ*—may be found in corpses long buried there is no inherent improbability in these flies living and propagating in the human intestine.

Other larvæ are also recorded as causes of intestinal

myiasis. Further observations on intestinal myiasis in the Tropics are required.

Dermal Myiasis.

In most cases of myiasis the flies have alternative methods of development, and a warm-blooded host is not essential for the life of the larva. In the *Œstridæ* the larva can only develop in such a host and are necessarily parasitic. A few may infest man, though their natural hosts are other animals. In Algeria *Œstris ovis* is to be found in man, but is not very common.

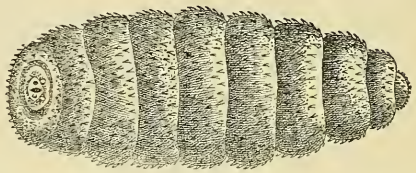


Fig. 83.—Cordylobia larva from the skin of man, South Africa. 3/1. (After Blanchard.)

The best known fly which deposits larvæ under the skin is the *Dermatobia cyaniventris* which is common on the eastern coast of Tropical America and in the West Indies. The larvæ are known by many names, "mosquito worm" and "ver macaque" being the most used (fig. 81). The larvæ are found singly in raised cutaneous swellings, usually on some uncovered part of the body. There is always a distinct opening from which black fluid exudes when the larva is nearly mature.

In Tropical Africa similar tumours are found due to the larvæ of a different class of fly. These larvæ are known as the "ver du Cayor," "tumba fly" (fig. 77), &c. The larvæ are not uncommon in Europeans and the tumours are usually in some part of the body covered by clothing.

The fly is the *Cordylobia anthropophaga*. It does not

belong to the Œstridæ, but to the Muscidæ. There is always a considerable amount of swelling and inflammatory œdema round the place where the larva is situated, both with the Dermatobia and the Cordylobia larvæ.

If forcible attempts are made to extract the larva, or an incision is made, a dangerous cellulitis may be set up in the case of either worm. A native remedy is to place a poultice

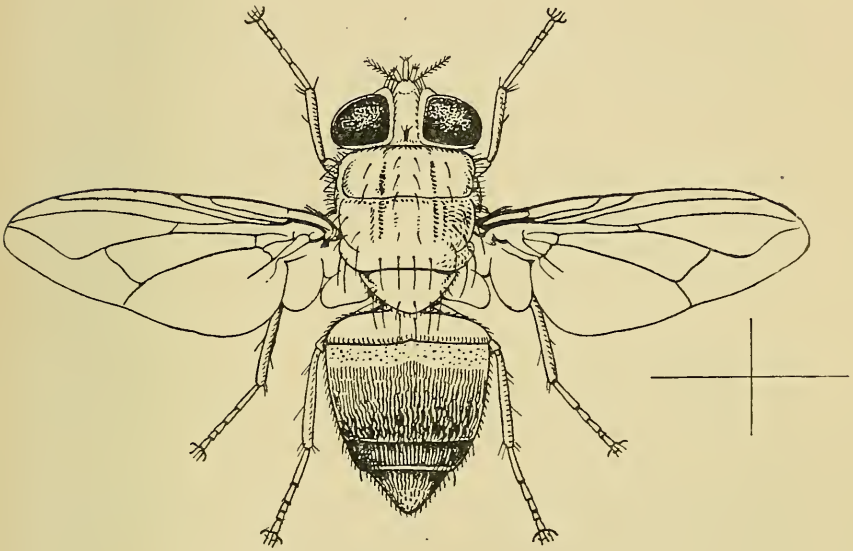


FIG. 84.—*Auchmeromyia luteola.*

of chewed leaves of tobacco so as to cover the orifice of the cyst. The larvæ will usually emerge and be found dead under the poultice. The air supply for these larvæ is obtained through the opening in the tumour, and if deprived of air they make their way out of the tumour. The more cleanly European treatment is to cover the orifice with a broad piece of strapping. It is nearly as effective as the native method.

The larva of only one fly is known to attack man. This occurs in Africa, and the blood-sucking larva is

popularly known as the "Congo floor maggot." The fly in general appearance closely resembles the *Cordylobia anthropophaga*, but differs from it mainly in the great length of the second abdominal segment. It is known as *Auchmeromyia luteola* (fig. 84).

Classification of Diptera concerned in Myiasis.

The more important biting flies were considered briefly in Part I. The non-biting flies that are the cause of the various forms of myiasis, and which are important as scavengers and as mechanical carriers of disease, belong to the division of the Diptera known as *Cyclorrhapha*.

In these the imago escapes from the pupal case by pushing off a circular cap at one end. In the adult the Cyclorrhapha can be recognized by the scar or depression that persists between the eyes and over the bases of the antennæ called the *lunula*. This lunula is the remnant of the bladder-like protrusion—ptilinum—which forms in the front of the head of the imago whilst it is still in the puparium, and which aids in pushing off the circular cap.

The flies in this group usually have a fairly simple wing venation, in most of them on the same plan as that of the house-fly. The antennæ are short, three-pointed, and have, usually at the base, on the third joint a projecting spine—*arista*—which may be covered with hairs to a varying extent. The antennæ in many cases are dependent, lying along the surface of the face.

The cyclorrhaphous diptera are a very large group, including over 20,000 species. This large number of species renders it necessary to divide and subdivide according to characters that would be too trivial to be considered of generic importance in other groups of the Diptera.

The Cyclorrhapha are divided into two big groups: the *Schizophora*, in which from the tips of the frontal lunule two sutures are continued downwards on the face; and the *Aschiza*, in which there is no such continuation of the lunule.

The *Aschiza* are of little importance in connection with disease, though rat-tailed larvæ of one of the families—*Syrphidæ*—are sometimes passed in the stool. When these have been identified the larvæ are those of *Eristalis tenax*. The syrphids vary greatly in appearance; they can always be recognized by the supporting incomplete vein running close to the fourth longitudinal (fig. 85).

One member of another family—*Phoridæ*—also causes intestinal myiasis.

This group consists of small, dark, hunchbacked flies with a very simple wing venation (fig. 86). The adults

FIG. 85. — Wing venation in *Syrphidæ*.

FIG. 86.— Wing venation in *Phoridæ*.

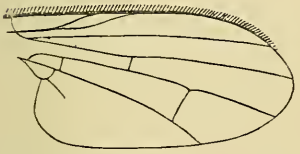


FIG. 87.—Wing venation in *Anthomyidæ*.

FIG. 88.—Wing venation in *Muscidæ*.

are capable of living and reproducing in the human intestines, so that larvæ of various ages and adult flies may be passed for months.

Sepsidæ are represented in man by *Piophila casei*. The larvæ "cheese mites," or "skippers," are sometimes passed in the stools, and are still alive.

The *Schizophora* are of more importance. The family includes some biting flies that are carriers of protozoa, such as Glossina, Stomoxys, which have been already considered. The non-biting flies are important as

causes of cutaneous and intestinal myiasis, and also all as mechanical carriers of disease, especially the common house-fly and other Muscidæ (in a general sense).

The characters of the spine or *arista* at the base of the third joint of the antennæ and variations in the fourth longitudinal vein enable the group to be subdivided into several families.

The more important are :—

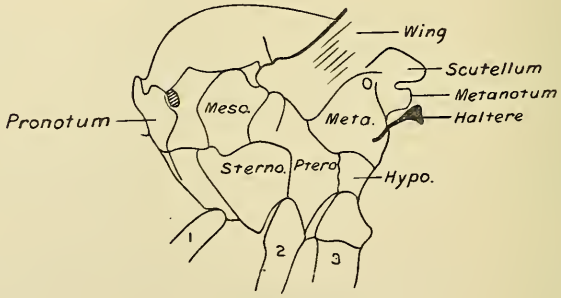
(1) *Anthomyidæ*. Arista plumose to tip; first posterior cell open (fig. 87); large squamæ, and eyes in male contiguous.

(2) *Muscidæ* (in restricted sense). Arista plumose to tip; no bristles on abdomen except at tip; first posterior cell more or less narrow at apex (fig. 88); abdomen, four visible segments.

(3) *Sarcophagidæ*. Arista plumose in part only; tip always bare; thorax usually light and dark stripes, and abdomen marbled in the same colour.

(4) *Tachinidæ*. Arista bare; abdomen hairy, often with spines; squamæ very large.

(5) *Œstridæ*. Head large, lower part swollen; arista usually bare; ocelli present, mouth-parts ill-developed, often rudimentary.



(After Williston.)

FIG. 89.—1, 2, 3, indicate first, second, and third pair of legs; *Meso.*, mesopleura; *Sterno.*, sternopleura; *Ptero.*, pteropleura; *Meta.*, metapleura; *Hypo.*, hypopleura. The presence or absence of hairs on this last is of great importance and enables the important genus *Musca* to be separated from other genera.

The first four of these used to be all included under Muscidæ, and are sometimes now grouped together as the super-family *Muscoidea*.

Of these groups : (1) Anthomyidæ includes the species most commonly represented in intestinal myiasis in temperate climates, as *Homalomyia canicularis*, and *Anthomyia desjardensis* is said to be not infrequent in Angola.

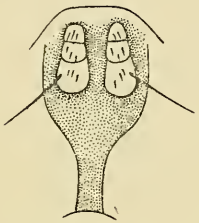
(2) *Muscidæ* are the most important group, and are subdivided according to the characters of mouth-parts, palps, character of hairs on antennæ, and minor differences in wing venation, particularly in the fourth longitudinal vein, presence of hairs on hypopleura (fig. 89) and coloration, into "genera."

	Mouth-parts formed for penetration		1
	Mouth-parts suctorial and not suitable for penetration		2
(1)	Includes Glossina, Stomoxys, Hæmatobia, &c. considered in Part I., as some of these are carriers of protozoa		
(2) *a*	No hypopleural bristles ; no bristle on inner side of middle tibia	*Musca.*	
	Hypopleural bristles; bristles on inner side of middle tibia		3
b	Large brown flies		4
	Black or brown or of dull metallic appearance		5
	Flies with brilliant metallic lustre		6
c	♀ Second abdominal segment not enlarged ; ♂ eyes close together	*Cordylobia.*	
	♀ Second abdominal segment greatly enlarged : ♂ eyes not approximated	*Auchmeromyia.*	
d	Mesonotum not flattened	*Calliphora.*	
	Mesonotum flattened behind transverse suture	*Protocalliphora.*	
e	Blue or green flies without longitudinal bands on mesonotum	*Lucilia.*	
	Blue and green flies with marked longitudinal bands on mesonotum	*Chrysomyia.*	
	Blue and green flies with dark bands on abdomen	*Pycnosoma.*	
	Stumpy flies with large heads and in the male with the eyes in contact	*Pycnosoma.*	

Cases both of intestinal and cutaneous myiasis are attributed to various species of Sarcophaga.

Œstridæ are of special importance, particularly in South America, as the various species of *Dermatobia* belong to this family, whilst in other parts of the world *Œstrus* may attack man as well as the lower animals.

Insects belonging to other orders are in many cases directly injurious to man. Of these, to avoid repetition, the fleas are considered in connection with plague, as the part they play in conveying that disease is of more importance than the local injuries they produce, though these in the case of the jigger are of considerable importance.



Antennæ and bare arista in *Œstridæ*.

Wing venation in *Œstridæ*.

FIG. 90.

The Hemiptera, bugs, and lice, are also considered with the diseases they carry.

The larva of a beetle was extracted from an abscess in the buttock of a European living in British Honduras by Dr. Cran, but no other cases are on record. The species to which the larva belonged is unknown.

CHAPTER XVII.

INSECT "PORTERS" OF DISEASE.

THOUGH the direct effects of the bites of insects or the ravages of their larvæ are sometimes serious, the diptera are more important as carriers of disease. In the case of certain protozoa and helminths they act as definitive intermediate hosts in which a part of the life of these organisms has necessarily to be spent, instances of which were considered when dealing with these parasites; or, in a purely mechanical manner, they convey and distribute germs of many diseases. When acting as mechanical carriers they are justly described as "porters" and the germs may belong to any class of pathogenic organisms, protozoa, helminths, or bacteria.

For an insect to be an efficient and important "porter" it must be (1) a fairly common species; (2) it must frequent places where, either in search of food or for oviposition, products containing germs of disease are present; and (3) it must have access to articles of food destined for human consumption, or to a surface or portion of the body capable of being directly infected by such germs.

The common house-fly, *Musca domestica*, fulfils all these conditions to a greater extent than any other insect, though a similar *rôle* to a minor extent may be carried out by other flies, by ants, and other insects.

M. domestica is found all the world over and at all times when suitable conditions of temperature are present. It feeds on sugar syrups, fruit, as well as fæces, and animal and vegetable refuse. It deposits its eggs on any

decaying vegetable matter and on litter fouled with ordure of horses, fowls, man, &c.

The larvæ hatch out from the eggs in eight hours to a few days. They move actively, burrow into or below the surface on which they are deposited, and moult in the case of *M. domestica* three times. They grow rapidly, but only remain a short time in fæces or animal matter, as when they get larger they migrate into vegetable refuse, into moist soft earth, or may penetrate some distance underground. In five days or much longer—several weeks—they become quiescent and the outer skin becomes smooth, hard and brown. The pupa contents fuse and become a white semi-fluid mass from which the parts of the fly become formed. After five to seven days or more a circular cap is forced off one end of the pupal case and the imago or fly emerges. If the larvæ have lived under favourable conditions and been well fed the flies when they hatch out are full size, but when food is scanty and conditions are unfavourable they are much smaller. In any case, after emergence from the puparium they do not increase in size. The flies become sexually mature in ten to fourteen days and four days later the females are able to lay eggs.

The diet of the larvæ is mainly vegetable, kitchen refuse, old stable refuse and the like. In the Tropics the refuse from sugar mills, megass, and any decaying vegetable masses are favourite breeding places. They do feed in excrement, human and otherwise, but usually leave it after a short time and burrow into the moist earth beneath. In a cesspit they are not to be found in or on the liquefied contents, and so cause little destruction of the excreta, in this respect differing widely from some of the Sarcophagidæ.

The adult, imago, whilst active probably lives only about three weeks, but in cold weather much longer, and may hibernate in England all through the winter. They are voracious feeders and will travel considerable distances for food or for suitable places and substances on which

to deposit their eggs. Their habits are diurnal, but they prefer shady places, and at night are quiescent. Their power of flight is considerable, especially when aided by the wind, but when they reach a suitable resting-place they do not travel far from it.

In England the great breeding places are the huge deposits or middens of household refuse which disgrace the outskirts of many of our towns, fig. 91. From such a breeding place the flies after hatching out can travel half

FIG. 91.—Municipal rubbish heap.

a mile or more, but will enter the first rows of houses they meet, and will not then travel much farther. The width of two or three streets is sufficient to provide an effective barrier to the invasion, though the houses, and particularly provision shops, in the first and second streets will be full of flies.

The adult fly carries germs, mainly bacilli, in three ways: (1) The proboscis and limbs become fouled with the excrement or other material on which they rest and feed, and as these include any ulcerated surface, any

discharges from ulcers, or from the conjunctiva, they have abundant opportunities of picking up germs.

(2) After feeding, the flies for a period regurgitate the fluid parts of the food, pus, &c., and with the regurgitation are disgorged some of the organisms derived from the filth on which they have fed.

(3) Defæcation. Flies defæcate frequently when well fed, and the fæces will contain all organisms that have survived the passage down the intestines.

Probably direct fouling by contact and by regurgitation are the most important. The fluid regurgitated serves to soften substances such as sugar on which they rest, and in swallowing the syrup thus formed some organisms are left behind. There is always the possibility that the larvæ have derived some pathogenic organisms and transmitted them to the adult, but this is probably, in the case of *M. domestica* of minor importance, as many organisms are destroyed in the intestines of the larvæ before pupation, and in any case the later stages of larval life are passed in moist earth or decaying vegetable matter.

Musca domestica is oviparous. The adult lays eggs which hatch out into larvæ and maggots. In the case of other flies there are differences. Many of the Sarcophagidæ, for instance, are larviparous, and deposit living young larvæ on the surface of fæces and other animal matter. These larvæ live on and in the fæces, but in cesspits do not remain deep, as the deeper parts contain no oxygen, and are practically anaerobic. The larvæ grow rapidly, but remain on the upper layer of the fæces, and as fresh dejecta are dropped on the surface these are rapidly invaded by the large, partly mature, larvæ, and devoured. The larvæ will feed many times on the same mass, passing it rapidly through their intestines. With large larvæ all thin-shelled eggs, such as ankylostomes, are destroyed and many of the bacilli, whilst the fæces are rapidly deodorized, as observed in the Malay States. When the larvæ are fully mature they escape from the

cesspit and pupate. The contents of the puparium are as a rule sterile, and in the freshly hatched flies, though some spores and spore-bearing organisms are to be found, both the ordinary intestinal organisms and the colour-producing ones, added for experimental purposes, are absent.

The danger of these flies crawling on the fæcal mass and conveying portions of it on to animal food are of course great. Fortunately fresh meat is a greater attraction to them than cold cooked food, and the flies do not frequent houses to the same extent as the *M. domestica*.

Almost all the intestinal organisms belonging to the bacteria can be conveyed by flies in one way or other, and some experiments (Graham Smith) show that it is possible that eggs of tapeworms may be conveyed in this manner to susceptible animals, and so the infective agents may be distributed. *M. domestica* is the chief offender, and Bahr has shown that the prevalence of the dysentery season in Suva, Fiji, is related to the prevalence of this fly. Experimentally it can be shown that all the intestinal organisms, pathogenic as well as non-pathogenic, can be conveyed by the fouled flies and foul articles of food, milk, sugar, cooked meat, &c. They undoubtedly spread ophthalmia, as when fouled by the discharges from the conjunctiva they can, if they settle on or near the eyes of other persons, by regurgitation, direct fouling or defæcation, deposit the germs in the vicinity of the eyes, when they will be readily introduced.

Yaws is sometimes spread similarly, as the flies can convey *Spirochæta pertenuis* from the yaws tubercle to any ulcerated or abraded surface on which it rests.

Some flies, as *Glossina*, are nearly pupiparous. They deposit larvæ which are so mature that they are ready to pupate, and when passed do not feed, but are still motile and can pass into loose earth and there pupate. These flies may act as direct "porters" of trypanosomes, as when disturbed in feeding on an animal in whose blood

trypanosomes are present, they can if they rapidly complete their feed on a second person infect him with trypanosomes. The more important method of conveyance is after a sufficient interval for the parasites to develop and in the developed form to pass into the proboscis. Some flies, as the *Hippoboscidæ*, are truly pupiparous, as they deposit the pupa and not larvæ.

Some of the important Orthorrhaphous flies deposit eggs on vegetation at the edge of water or in the water itself, as in Tabanus and Chrysops. The larvæ which hatch out are aquatic or semi-aquatic, living in wet sand or earth, and the flies may, as in the case of *Chrysops dimidiata* and *Filaria loa*, act as alternative hosts of parasites, but we do not know so far if they act as porters of disease. This action is not likely in these instances to be important.

For fuller information as regards "flies" the reader is advised to study "Entomology for Medical Officers," by A. Alcock, C.I.E., M.B., LL.D., F.R.S., Indian Medical Service (retired), Lecturer on Medical Entomology, &c., at the London School of Tropical Medicine. Gurney and Jackson, 33, Paternoster Row, London. 1911. Price 9s. net.

CHAPTER XVIII.

SNAKES AND SNAKE-VENOMS.

By A. Alcock, M.B., LL.D., F.R.S.

CONTENTS.

§ 1. General Zoological Characters and Classification of Snakes.
§ 2. Venom-apparatus and Venom of Thanatophidia.
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§ 4. Genera and Species of Venomous Snakes, and their Geographical Distribution.

In all ages and among all races snakes have been emblems of mystery or objects of dread. Whether we look back to antiquity—to Egypt, to Syria, to Greece, to the ancient civilizations of America—or whether we turn to the Eastern communities of to-day, always we find the serpent either typifying wisdom and subtlety unfathomable, or linked in some way with the supernatural. Nor has the progress of science, inimical to superstition, altogether dispelled the horror that lurks about a snake; for, whether or not we accept the Indian tale of 20,000 deaths a year from snake-bite, we cannot but regard a creeping thing that, to satisfy no necessary appetite, may suddenly strike a strong man dead, as something beyond measure fell and tragical, "cursed above all cattle and above every beast of the field."

The researches of the last twenty-five years, however, have revealed at least the general nature and modes of action of the more formidable snake-venoms, and how their effective antidotes are to be obtained. We know that the active components of snake-venoms are soluble proteids belonging to the class of toxins and enzymes. We know that animals can be immunized to these toxic

constituents of venom in the same way as they can be immunized to bacterial toxins, and that the blood-serum of the immunized animals develops antagonistic bodies, or antivenoms, comparable with the bacterial antitoxins of modern therapeutics. We have, moreover, considerable experimental evidence that just as the various bacterial antitoxins are specific, so also these antivenoms are specific, that is to say, any given antivenom is antagonistic only to the venom of the particular species of snake that elicits it. This well-grounded belief in the *specific* limitations of antivenoms makes it incumbent on every medical man, who hopes to follow the modern treatment of snake-bite by antivenomous sera in a rational manner, to know something more than how merely to recognize a venomous snake as such. He must be able to distinguish species; and to this end it is advisable for him to understand how and upon what structural characters snakes are classified, and to appreciate the value of specific criteria; and his work will be made easier if he also knows what genera and species he may expect to find in any particular locality.

§ 1. General Zoological Characters and Classification of Snakes.

The Snakes (*Ophidia*) form an Order of the Class of Reptiles, and are distinguished by their elongate, limbless body covered by horny epidermal scales, by their wonderfully flexible mouth, by the absence of eyelids and of a tympanic cavity and external ear-opening, and by having the cloacal orifice transverse, and the penis paired. The extraordinary distensibility of the mouth is due partly to the length and mobility of the quadrate bone (*q.*, fig. 95), from which the jaws and bony palate are suspended, partly to the looseness of the attachment of the individual bones of the upper jaw and palate, and very largely to the fact that the rami of the lower jaw are loosely held together by an elastic symphyseal

ligament, and so can be widely separated in a horizontal plane.

In respect of the elongate body and the absence of limbs, there are numerous lizards and some amphibia that resemble snakes, but the means by which these and certain other snake-like animals can be discriminated will be considered presently.

In the absence of limbs locomotion is effected by the flexibility of the backbone, and by the mobility of the ribs. Every vertebra in front of the cloacal level, except the atlas, carries a pair of ribs, the free ends of which are attached to the tissue underlying the large epidermal scales (shields) of the belly, so that a snake crawls on the ends of its ribs, acting upon the belly-shields.

The tongue of snakes must be mentioned, as, although it is merely a very protractile organ of touch, it is commonly mistaken for a weapon of offence or sting. The tongue consists of a basal sheath, and two long, slender, pointed, muscular cylinders — separated in their distal half—which can be shot out of the sheath even when the jaws are shut. A similar forked and ensheathed tongue occurs in certain lizards.

For the recognition of snakes it is necessary to understand the terminology of the scales, especially of those covering the head, and to know something of the skull and dentition.

The scales of snakes are horny plates of epidermis, the superficial cuticular layer of which is moulted periodically *en masse*. On the back and sides of the body they are small, and are arranged in overlapping rows. On the belly they are often much enlarged, and are then known as *shields—ventral shields* in front of the cloacal opening, *sub-caudal* shields behind that point. On the head also they often have the form of large shields, which touch only by their edges.

The shields of the head are best studied in a harmless Colubrine snake, such as is represented in figs. 92 to 94, as a type.

On the top of the head (fig. 92), we observe, from before backwards, the *rostral* (*r.*) covering the tip of the snout; a pair of *internasals* (*i.n.*) between the nostrils; a pair of *prefrontals* (*p.f.*); a large *frontal* (*f.*) flanked on either side by a *supra-ocular* or *supra-orbital* (*s.o.*) between

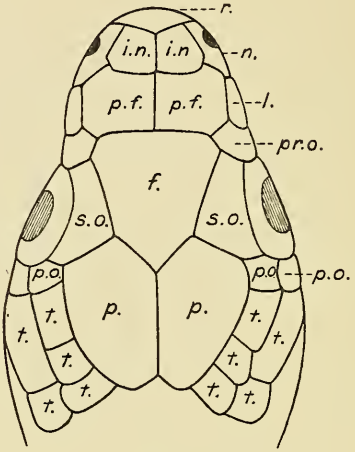


FIG. 92.

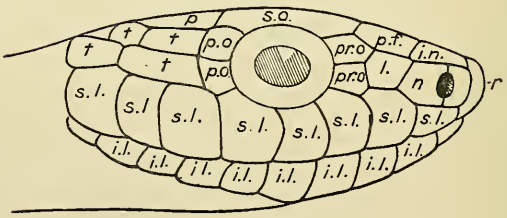


FIG. 93.

the eyes; a pair of large *parietals* (*p.*); and two rows of smallish *temporals* (*t.t.*). Sometimes there is a pair of large *occipitals* immediately behind the parietals; this is the case in the formidable "king cobra" (*Naia bungarus*) of Southern Asia.

On the side of the head (fig. 93) we distinguish the *rostral* (*r.*) covering the tip of the snout; the *upper labials* (*s.l.*) covering the upper lip, and the *lower labials* (*i.l.*) covering the lower lip; the *nasal* (*n.*) pierced by the nostril; the *preoculars* (*pr.o.*) in front of the eye, and the *post-oculars* (*p.o.*) behind it; and the *temporals* (*t.t.*) behind the post-oculars. Between the nasal and pre-ocular in *all but a few* harmless Colubrines, and *quite*

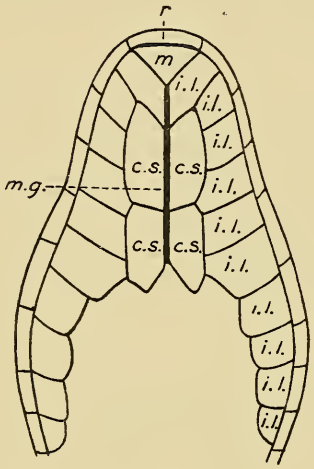


FIG. 94.

exceptionally in poisonous Colubrines, lies a *loreal* shield. Importance has often been attached to the presence or absence of the loreal shield as a supposed index of the nature of the snake—whether poisonous or otherwise. It is an uncertain index even for Colubrines, and is not at all applicable to Viperines, of which latter all are poisonous and many possess a loreal shield. The upper labials commonly touch the eye, but sometimes there are some small intervening *subocular*s.

On the under side of the head (fig. 94) the shields bearing special names are the *lower labials* (*l.l.*); the *mental* (*m.*) in the middle line of the mouth and chin,

subjacent to the rostral; and two pairs of *chin-shields* (*c.s.*), one behind the other, immediately posterior to the first lower labial. Between the chin-shields in most snakes is a longitudinal furrow, the *mental groove* (*m.g.*), which permits lateral stretching of the mouth.

As regards the snake's skull, we need only consider those bones that enter into the formation of the jaws and palate, as displayed in a harmless Colubrine snake (figs. 95 and 96): a very rough dissection is all that is necessary to expose them.

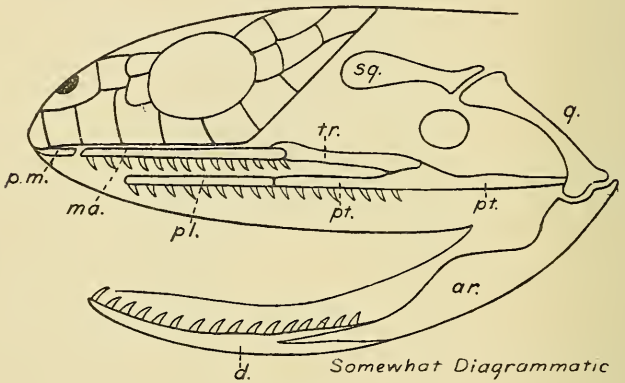


FIG. 95.

In all snakes the lower jaw, and in many snakes the backstay of the bony palate and upper jaw also, are slung at the end of a long mobile *quadrate bone* (*q.*), which hangs freely from the cranium on either side. In most snakes the quadrate does not articulate directly with the cranium, but, for increased mobility, is attached to a longish bone, the *squamosal* (*sq.*), which lies loosely on the cranium. Each ramus of the mandible, or lower jaw, is composed of several bones, among which an *articular* (*ar.*) and a *dentary* (*d.*) are always recognizable: the articular, which is toothless, articulates with the quadrate, and is firmly spliced into the dentary, which usually bears

teeth. In the dry skull the distal ends of the dentary bones are free. In some snakes, but not in any of the families that include poisonous species, there is another bone of importance in classification, the *coronoid* (fig. 97), which forms a sort of internal splint at the upper angle of the splice between the articular and dentary bones.

The chief bone of the upper jaw, on either side, is the *maxilla* (*ma.*), which is usually armed with teeth, and more or less movably attached to the base of the skull.

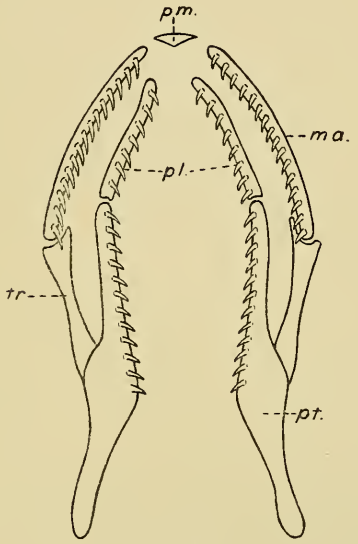


FIG. 96.

Between the maxillæ is a small, unpaired *premaxilla* (*p.m.*) which in all poisonous snakes is toothless. Parallel with the maxillæ on either side are the *palatines* (*pl.*) and *pterygoids* (*pt.*), which form the bony roof of the mouth and are generally toothed : both these bones are largely independent of the base of the skull, and the pterygoid commonly articulates with the quadrate. An important part of the mechanism of the upper jaw is the *transpalatine* or *ectopterygoid* bone (*tr.*), which stretches from

the pterygoid to the maxilla, and in many poisonous snakes acts as a lever for the erection of the latter. This function of the transpalatine is very evident in all the vipers; when the mouth is opened the distal end of the quadrate is advanced, the pterygoid and transpalatine are thus thrust forward, and the maxilla consequently is erected. This movement of the maxilla is quite limited in the *Colubridæ*.

The teeth of snakes are merely recurved hooks for holding the prey, which is bolted whole. Teeth may be present on all the bones that compose the jaws and palate, except the transpalatine. Their attachment (ankylosis) to the bone is superficial, and they are easily broken off, but are readily renewed. In some snakes some of the larger teeth are longitudinally grooved on their anterior, convex surface, to carry saliva into the bite, and in the venomous snakes these enlarged and channelled teeth form the poison-fangs, which are described further on.

Animals that may be confused with Snakes.—There are numerous snake-like lizards; and also the burrowing, limbless amphibia of the order *Apoda* may be mistaken for snakes. Again, in Indo-Pacific waters, eels and sea-snakes might be confounded. Even earthworms have sometimes caused perplexity to undiscriminating observers. Quite apart from morphological differences that are discovered by dissection, snakes can always be distinguished by the absence of a bony mandibular symphysis, and by their long, forked, protrusible tongue, retractile into a basal sheath. There are lizards—and some of them are snake-like—that have a forked, and even a more or less protractile, tongue; but the only lizards whose tongue is quite snake-like possess well-developed limbs. Some of the limbless lizards, again, have movable eyelids and an external ear-opening. In the snake-like apodous Amphibia the cloacal orifice is at the very end of the body; there is usually, behind each nostril, a small pit containing a papilla-like tentacle;

and when scales are present they are minute, and are deeply embedded in the skin. Eels, even if they have scales and have not fins of any kind, always have at least one external gill-opening.

The *habits of Snakes*, in so far as one may desire to study them with a view to avoiding the dangerous species, will be dealt with at the end of this article.

Classification of Snakes.—About 1,700 species of snakes are known, of which rather more than 300 have efficient poison-fangs, and so must be classed as "venomous," while 300 more possess grooved teeth of a sort, and so, though not commonly regarded as venomous, can instil saliva into their bite, and can thus inflict a wound that must be regarded with suspicion or even with dread.

These 1,700 species are distributed in nine families, and though only two of the families include venomous and "suspicious" species, it is just as well, for many reasons, not to ignore completely those forms which, though harmless, may come to the notice of a medical officer in the Tropics.

(*A*) The snakes of the following seven families are, so far as their bite is concerned, innocuous :—

(1) *Typhlopidæ* (Blindworm Snakes). — These are burrowing snakes that live underground, and feed chiefly on earthworms and grubs. They are found all round the globe in tropical and warmer temperate latitudes, one of the hundred and odd species known ranging into South-eastern Europe. The smaller species are not much bigger than an earthworm, and the largest does not attain a length of 30 inches. They can be recognized by their cylindrical body; by their hard, shiny, cycloid scales; by their minute eyes, which lie *beneath* the shields of the head; and by the fact that the scales of the belly are quite like those covering the rest of the body—*i.e.*, by the *absence of enlarged ventral shields*. Their chief skeletal peculiarities are the possession of a vestigial pelvis, the presence of a coronoid bone in the mandible, and the absence of squamosal and transpalatine

bones. The only teeth present are two or three in each maxilla.

In Calcutta, when water was supplied on the intermittent system, it used to be not uncommon, at certain seasons, for a small species of *Typhlops* to creep, somehow or other, into the mains, and eventually to be discharged in the efflux from taps, to the consternation of the householder.

(2) *Glauconiidæ*.—In form, external appearance, and habits these snakes resemble *Typhlopidæ*, with which they also agree in most of their skeletal characters, differing in the form of the upper jaw, and in having teeth only in the mandible. It is a small family of about thirty species, found for the most part in Africa and Tropical America, but occurring also in Southern Asia.

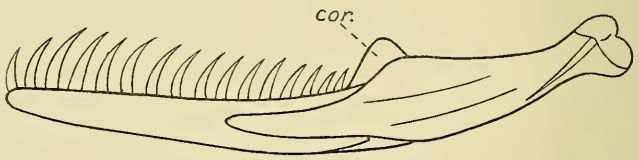


FIG. 97.

(3) *Boiidæ* (Boas and Pythons).—This family includes about seventy species, some of which attain a length of 30 ft., and are of formidable strength, being able to overpower and crush large prey. They are found in all warm parts of the world, one species ranging into South-eastern Europe. Apart from all hidden differences of structure, they can be distinguished from any venomous *land*-snake by their ventral shields, which, though enlarged, are of moderate size, and do not extend to the flanks. As Major Wall expresses it, if a Boiid snake be placed back downwards and belly upwards, at least one complete row—probably two or three rows—of the small scales of the flanks will be seen on either side of the ventral shields in that position. As regards skeletal differences, the *Boiidæ* have vestiges of a pelvis

and femora, and the femora may even terminate each in a claw, which may be externally visible on either side of the cloacal opening. The mandible includes a coronoid bone (fig. 97, *cor.*). Squamosals and transpalatines are present.

(4) *Ilysiidæ*.—This family is composed of about half a dozen species, which are found only in Tropical America, and in the islands and peninsulas of South-eastern Asia. Their characters are those of the *Boiidæ*, except that they do not attain any great size, and that the squamosal and quadrate bones are much reduced, and the ventral shields are quite small. One of the common South American species of this family is coloured in alternate broad rings of black and red, like some of the venomous Colubrine snakes of the genus *Elaps* of the same region.

(5) *Uropeltidæ* (Shield-tails and Peg-tails).—These small burrowing-snakes, of which about forty species are known, are restricted to the hill-jungles of Ceylon and Southern India. They have a peculiar stumpy or obliquely truncated tail, ending either in a large rough shield, or in a spike or pair of points. The eyes are small, and the ventral shields are only slightly enlarged.

(6) *Xenopeltidæ*.—This family is represented by a single species, which is found only in Southern India, Burma and Indo-China, and the Malay Peninsula and neighbouring islands. It closely resembles a land Colubrine snake in all its characters, but the ventral shields, though large, do not extend on to the flanks. There are teeth in the premaxilla.

(7) *Amblycephalidæ*.—This is a small family—there are between thirty and forty species—of insect-eating snakes, restricted, like the *Ilysiidæ*, to South-eastern Asia and Tropical America. Superficially they much resemble Colubrine snakes, as they have large ventral shields which extend on to the flanks; and some species have a strong superficial resemblance to certain venomous Colubrines; but they may be at once distinguished by the

absence of a mental groove (fig. 94, *m.g.*). Furthermore, the squamosal bone is rudimentary, and the pterygoid does not nearly reach to the quadrate.

(*B*) The two families to which the poisonous snakes, or Thanatophidia (Greek θάνατος = death, and ὄφις = a snake) belong are the *Colubridæ* and the *Viperidæ*. In both of them squamosal and transpalatines are present (fig. 95), the pterygoid extends backwards to the quadrate (fig. 95), and the mandible is without a coronoid bone. In both of them—certain aquatic Colubrines, both venomous and non-venomous, excepted—the ventral shields are so much enlarged transversely that their ends can usually be seen in a lateral view. Or, as Major Wall puts it, if the snake is looked at as it lies on a table, belly upwards, the most that can be seen besides the ventral shields is a glimpse of a single line of lateral scales. Of course, it is assumed that the belly of the snake is not distended with food; if the stomach be full this character is fallacious.

Though a typical viper is easy to distinguish from a typical Colubrine snake, there are not a few vipers that may be mistaken for Colubrines, and *vice versa*. The safest criterion is the form of the maxilla: in *Colubridæ* the maxilla is horizontal, and is usually of some length; in *Viperidæ* the maxilla is a very short bone, is not horizontal, and can be erected for action quite perpendicular to the palate.

Colubridæ.

(1) *Colubridæ*.—In the great majority of snakes of this family the head is covered with large symmetrically arranged shields (figs. 92 to 94), and the ventral shields are so much broadened transversely—except in certain aquatic species—that their ends are visible in a lateral view: the maxilla is horizontal, and in many species carries a considerable number of teeth. The family is a very large one, numbering nearly 1,300 species, or more than three times as many species as all the other families

put together, and is represented in all parts of the world —New Zealand excepted—that are not too cold, as well as in the seas and estuaries of the Indo-Pacific. It is divided into three sections, according to the form of the teeth, namely, *Aglypha*, *Opisthoglypha*, and *Proteroglypha*.

(*a*) *Aglypha* (Greek *a* privative, and γλυφή = a carving or groove).—In the Aglypha the maxilla is generally long, and armed with numerous teeth : none of the teeth are grooved, though some of them may be enlarged. All the Aglyphe Colubrines are *harmless;* for although they possess glands which are homologous with the poison-glands of venomous snakes, and the secretion of which, in some species at least, when experimentally extracted and injected into small animals has been observed to have distinct toxic properties, they are without special means of instilling the secretion into their bite. Most of the Aglypha have a loreal shield (fig. 93), but some have not: in most of them none of the maxillary teeth are enlarged, but there are a few species in which some of these teeth are almost large enough to be mistaken for small poison-fangs. In any case of doubt the tooth must be examined with a lens to see whether it is longitudinally grooved on its anterior surface or not. There are more than 700 species of harmless *Colubridæ :* most of them are land-snakes; but a few of them are thoroughly aquatic, and though the aquatic species chiefly frequent rivers some of them are marine, and as the marine species are found in the same seas with the venomous sea-snakes they have to be carefully distinguished from the latter by an examination of the teeth and tail.

(*b*) *Opisthoglypha* (Greek ὄπισθεν = behind, and γλυφή = groove).—In the Opisthoglypha the maxilla is generally long and many-toothed : one or more of the *posterior* teeth in the maxilla are enlarged and are longitudinally grooved on the anterior surface, the groove being a very open one (fig. 98, *gr.*).

As the Opisthoglyphe Colubrines possess a gland that is homologous with the poison-gland of the venomous

species, and as its secretion is known in many cases to be fatal to small animals and in some cases to be dangerous even to large animals, and as moreover they have grooved fangs for instilling the secretion, they certainly cannot be called harmless. Some good authorities consider them to be truly venomous, but do not include them among *Thanatophidia* for the sole reason that the fangs, being placed far back in the jaw, can be used with effect only upon a small animal that is engulfed in the mouth, and are unlikely to wound a large animal that is struck at and merely bitten superficially. It is usual to term them "suspicious." There are about 300 species of them: most of them are land-snakes, but not

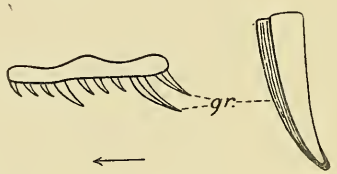


FIG. 98.

a few are aquatic, and may be found off shore in the same seas with the *Hydrophinæ*. Apart from dentition, the aquatic Opisthoglyphes, like the aquatic Aglyphes, can be discriminated from the *Hydrophinæ* by the form of the tail, which, though it may be compressed to a certain extent, is *not paddle-like*. Exact observations upon the venom of the Opisthoglyphe Colubrines are very much needed. (See p. 249.)

(*c*) *Proteroglypha* (Greek πρότερον = in front, and γλυφή = groove). In the Proteroglypha the maxilla is of moderate length or short, and seldom has very many teeth: one or two of the *anterior* teeth in the maxilla are poison-fangs (fig. 99, *p*), generally much enlarged, and so deeply grooved and folded as to appear tubular. Sometimes some of the smaller teeth of the maxilla, or even of the mandible, may also be grooved.

All the Proteroglyphe Colubrines are included among *Thanatophidia*, although the bite of all is not, even when untreated, necessarily fatal. There are about 200 species of them, and they are grouped in two subfamilies, namely, *Elapinæ*, or poisonous land-colubrines, and *Hydrophinæ*, or poisonous sea-snakes.

(i) *Hydrophinæ*.—In the poisonous sea-snakes the tail is very strongly compressed like the blade of a paddle: this, and the poison fangs in the front of the upper jaw, distinguishes them from the aquatic snakes that belong to the harmless and "suspicious" groups. There are between fifty and sixty species of Hydrophinæ, and they are restricted to the Indian and Pacific oceans in the

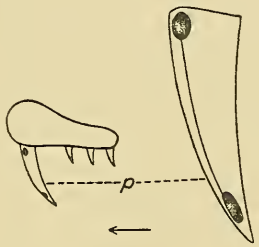


FIG. 99.

tropical and warmer temperate latitudes: though their range extends from Madagascar to Panama, their head-quarters, where they abound, lie between the Persian Gulf and the seas of China and North Australia. Off the coasts of India they may sometimes be seen in swarms, like shoals of fish. Though they are thoroughly marine they are fond of estuaries, and may travel a long way up tidal rivers into fresh water: one species is confined to a fresh-water lake in the Philippines: a few species may wander ashore, and in these alone the ventral shields are large, and the nostrils are lateral instead of superior. Sea-snakes of this subfamily are, when caught uninjured, very shy and inoffensive; but the venom of those species in which its properties have been tested is perhaps the most virulent known.

(ii) *Elapinæ.*—In this subfamily the tail is of the ordinary tapering, cylindrical kind : the head is covered with large shields, and the ventral shields are enlarged transversely. There are about 140 species, of which nearly half belong to the Australian region, and the other half are divided pretty equally between Africa, Southern Asia and its islands, and the tropical and subtropical parts of the American continent and islands. The exact geographical distribution of the more important forms will be considered subsequently, together with that of the more notorious *Viperidæ.*

Viperidæ.

(2) *Viperidæ.* — All the snakes — about 110 species — of this family are more or less poisonous, possessing not only a poison-gland, but also large tubular poison-fangs for injecting the venom. It is popularly supposed to be easy to distinguish a Viperine from any Colubrine snake by the narrow neck, by the very broad head

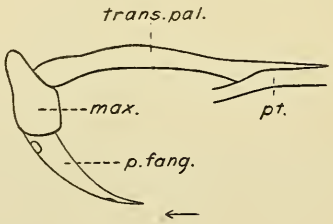


Fig. 100.

covered with small scales, by the elliptical pupil, and by the stumpy tail. But there are Colubrines in which these features are present, singly, or even in some combination ; and, on the other hand, there are not a few vipers that are without one or more of these supposed characteristic features. The distinctive mark of the *Viperidæ* is the maxilla (fig. 100), which is a very short bone hanging obliquely to the palate, and capable of being "erected" into a perpendicular position.

In the maxilla the only teeth are the poison-fangs—one or two large tubular fangs ankylosed to the bone—and a bunch of unattached "reserve" fangs behind.

Viperidæ are not found in the Australian region or in Madagascar, but occur in Europe, Asia, Africa, and America. They are divided into two subfamilies, *Viperinæ* and *Crotalinæ*.

(i) *Viperinæ*.—Ordinary vipers without a loreal pit. About forty-five species, of which more than half are African, and the others are found in Asia and Europe: some of the species have a wide range, and are common to Europe and Asia, or to Asia and Africa, or even, rarely, to all three continents. None in America.

(ii) *Crotalinæ*.—Vipers with a large sensory pit—the loreal pit—between the eye and the nostril. About sixty-five species, of which nearly two-thirds are American and the remainder Asiatic. Among the American species the rattlesnakes are included.

§ 2. The Venom-apparatus and Venom of Thanatophidia.

The Venom Apparatus.—The venom is secreted by a pair of glands which are commonly regarded as homologous with the parotids of mammals: it is injected by special fangs situated in the front of the maxillæ, and is conveyed from the gland by a short duct, the end of which is merely applied, not attached, to the base of the fang.

The gland is a racemose or tubulo-racemose gland, enclosed in a tough fibrous capsule (fig. 101). As a rule it is about the size and shape of a shelled almond, and lies, on either side, in the temporal region immediately behind the eye (fig, 101, *gl.*); but it occasionally has the form of a long cord or ribbon extending far back in the anterior third of the body. It is for the most part subcutaneous, but in glands of the usual form its posterior portion is covered by the fascia and some fibres of the

masseter muscle (fig. 101, *mas.*, shows the line of cover). In some cases the capsule has ligamentous attachments to the quadrato-mandibular joint. Thus there is close connection between the gland and the motor mechanism of the jaw, so that when the snake bites the gland is compressed, the duct stretched, and the poison squeezed along the duct.

The duct (fig. 101, *d.*), enclosed in the same capsule with the gland, runs below the eye, and immediately beneath the skin of the upper lip, embedded in a mass of *upper labial glands.* Just in front of the fang it is recurved downwards to open on the anterior surface of the fold of mucous membrane (fig. 94, *sh.*) in which the

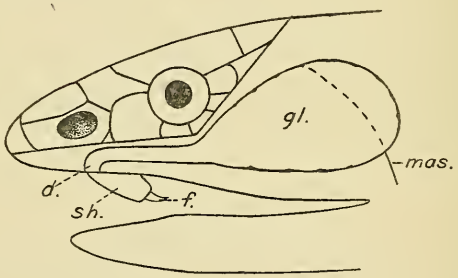


FIG. 101.

fang is ensheathed, in such a way that when the fang is erected the opening of the duct is closely applied to the corresponding opening in the fang.

The fang (figs. 99, 100, 101) is an amplification of the grooved tooth (fig. 98) of certain "suspicious" Colubrines. The open groove on the anterior surface of the tooth has now become, by an infolding of its edges, a canal with only the ends open. In some sea-snakes the edges though much inflexed do not meet; but in other Thanatophidia they meet to form a tube, with one opening near the base of the fang to which the orifice of the poison-duct is applied, and another near the point of the fang through which the poison is ejected. Except

in some of the *Viperidæ* these two openings are connected by a fine seam marking the line of closure of the edges of the groove. In some rare cases the fang is not grooved at all.

In repose the poison-fangs are more or less obliquely recumbent, and are more or less concealed in a sheath of mucous membrane; in action they are erected by the rotation of the maxillæ, which is particularly free in the *Viperidæ*, though quite limited in the Colubrines. In some Elapines and sea-snakes the poison-fangs are small; in some of the big *Viperidæ* they are over an inch long.

In rear of the poison-fangs, and in the same mucous sheath, is a bunch of "reserve" fangs; in the *Viperidæ* there are no teeth in the maxilla, except the fang and its reserves; but in most venomous *Colubridæ* there are additional small teeth, which may either be grooved or, more commonly, simple. It is to be understood that the canal of the poison-fangs has nothing to do with the pulp-cavity, which lies, as usual, in the body of the tooth.

The venom is forcibly ejected through the fangs by the act of biting. When a snake bites it lays hold like a bulldog, the muscles of its jaws can be seen vigorously working, and in many snakes the venom is effectively injected only in this way. But it is also certain that in some cases—particularly, according to Dr. H. E. Arbuckle, in the viper *Causus rhombeatus*—the gland itself is contractile, and is capable, when artificially stimulated in the unconscious snake, of ejecting its secretion through the fang. This may explain the accounts of snakes that spit poison; although it is possible that in these "spitting snakes" it may be the secretion of the labial glands that is spurted out. At any rate, it is stated that *C. rhombeatus* dribbles poison from its fangs, and that some of the Indian and African Colubrines can spit venom.

The amount of venom spent at one act varies according to species, from two or three drops in some sea-snakes to thirty drops in a large "king cobra"; of course in any given species the amount depends upon the size of the

individual and its condition at the moment—whether fresh or exhausted, fasting or full, long captive or new-taken, &c. In experimental work the amount is estimated by carefully drying and weighing the secretion obtained by firm pressure on the glands of the living snake. Major Lamb estimates that a cobra of middle size will thus yield about 200 mgm. of dried venom, sufficient to kill eight average men.

Physical and Chemical Characters of Venom.—Snake-venom is a clear (sometimes opalescent), slightly viscid fluid of a yellow colour; it is odourless, tasteless (sometimes bitter), of a very high specific gravity, and in normal reaction acid. It is rich in soluble proteids, and it is to these, as was first demonstrated by Weir Mitchell in 1874, that it owes its virulence. Some of these proteids—notably those that predominate in the venom of *Viperidæ*—are coagulated and impaired in power by heat short of boiling point, and are destroyed by gastric juice. Others—notably those that predominate in the venom of *Colubridæ*—are not. All, however, are destroyed by *prolonged* boiling and by pancreatic juice.

Snake-venoms give the usual proteid reactions, and are rendered inert by the various chemical reagents—*e.g.*, strong caustics, and strong oxidizing agents like permanganate of potash and hypochlorite of lime—that destroy proteids or precipitate them from solution. They can be dried in the usual ways. Dried venom breaks into lumps, or flakes, or needles, like gum-arabic or iodoform. When properly dried it keeps indefinitely; it dissolves again readily in saline solution or water, and the solution is fully potent.

Nature and Action of Venom. — From the biological standpoint it is safe to regard snake-venom as essentially part of the digestive mechanism; to an animal that swallows relatively enormous prey with integuments practically intact, it must be a crucial advantage to be able to impregnate the prey with powerful ferments and solvents.

Snake-venoms are analogous with toxins and enzymes; they are of all degrees of potency and complexity, being not quite alike even in snakes of closely related species. In a general view their principal but not their only toxic components may be classed, according to their action, into (*a*) those which act upon the central nerve system—neurotoxins; and (*b*) those which act upon the blood and vascular system. In the latter, again, several kinds are included, the chief of which are those which destroy (*a*) the red blood cells (hæmolysins), and (*b*) the cells of the capillary walls (hæmorrhagins), and thus diminish both the coagulability of the blood and the continence of the blood-vessels; (*c*) those which act upon the plasma and increase the coagulability of the blood (fibrin ferments); and (*d*) those which act directly upon the heart and vaso-motor system. Of the neurotoxins it is known that they show a selective affinity for the cells of the respiratory centre in the medulla.

It is generally agreed that neurotoxins (with a special affinity for the breathing centre) preponderate in the venom of *Colubridæ*, and that toxins that act upon the blood and circulatory system preponderate in the venom of *Viperidæ*, and that among the *Australian* Colubrines venoms rich in both classes of toxins are not rare.

It must be understood that the toxins mentioned in this brief review are far from being the only toxins known; and, furthermore, that with any given venom—and especially with venoms that act chiefly on the blood—one toxic effect or another may be either emphasized or masked, according to the amount of venom injected and the rapidity with which it is absorbed.

Effects of Venom upon Animals.—It is obvious that these must differ, not only with different kinds of venom, but also with the condition of the venom at the moment, with the amount of venom injected, and with the manner of injection, whether intravascular (rapid) or subcutaneous (slow). The matter cannot be treated quite concisely, the simplest plan is to consider some typical examples of the different kinds of venom.

(*a*) *Effects of Indian Cobra Venom: exemplifying a Typical Elapine Snake.*—Experimentally, in animals, the usual symptoms of a lethal charge are gradually increasing paralysis, beginning with the hind limbs, until the animal lies in a state of drowsiness, with twitchings, and nodding and jerking of the head. Breathing becomes laboured, and at last fails rapidly in gasps, and the animal expires after, perhaps, a few convulsions. After death the heart continues to beat for a time; the blood may clot well, or slowly and ill; and there may be, or may not be, dissolution of red blood cells. At the site of injection there is some extravasation and infiltration. In mammals salivation is common.

In a man bitten by a cobra the effects are much the same, and appear from ten minutes to two hours after the bite is inflicted. Locally there is immediate burning, tingling, and numbness, followed by a certain amount of inflammation, and perhaps by oozing of bloody serum from the punctures. The general symptoms begin with drowsiness, weakness, and unsteadiness on the legs. Soon the victim lies, unable to move, or speak, or swallow, with saliva bubbling from his mouth, and with the pupils usually contracted, though not insensitive to light; but not entirely unconscious. Nausea and vomiting often occur. The breathing becomes slow and stertorous, and the victim gradually becomes comatose. In a fatal case the coma deepens and the breathing stops, and the pulse, which may have been fairly good, stops soon afterwards. The end has been known to come within an hour of the infliction of the bite, or, on the other hand, not till nearly two days afterwards; it usually occurs in five to twelve hours. In a happy case the paralysis passes off and the patient rapidly recovers; in cases that recover, sloughing is restricted to the immediate site of the wound; there is no deep and extensively spreading destruction of tissue.

The predominant features in cobra poisoning are: (1) General paralysis, and special paralysis of the breathing mechanism, due to the neurotoxin; and (2) more or less delay in the onset of the symptoms.

(*b*) *Effects of the Venoms of Russell's Viper and of Echis carinatus: exemplifying Typical Viperine Snakes.* — In Fayrer's classical experiments the action of the venom of Russell's viper is well illustrated. A viper of this species was made to bite a full-grown fowl: the fowl immediately fell over in violent convulsions, and in less than ninety seconds was dead. According to Major Lamb, when Russell's venom is injected into the blood-stream of an animal there is general clotting of the blood in the vessels, causing asphyxic convulsions, and the heart stops dead. When the venom is injected under the skin the animal staggers and lies down; it may rise only to collapse again. If death does not occur at once the wound and various mucous surfaces begin to bleed, owing to destruction and abnormal fluidity of the blood, and to dissolution of the capillary walls. Locally there is severe inflammation spreading far from the wound, and enormous gangrenous destruction of tissue, providing superlative conditions for secondary bacterial infection.

In a man bitten by Russell's viper similar effects ensue. Locally there is great pain and swelling, and extensive extravasation. The general symptoms are those of rapid syncope and collapse, with cold sweats, nausea, vomiting, and dilated pupils insensitive to light. If the victim recovers from the collapse bleeding from the mucous membranes may follow, and there is albuminuria or hæmaturia. Should there be recovery the local symptoms become urgent; there is extensive suppuration and necrosis of tissue, extending far beyond the wound, and this may lead to fatal septicæmia.

The action of the venom of *Echis carinatus* is quite like that of Russell's viper. Major Lamb states that a small quantity injected into the blood-stream of an animal causes rapid intravascular clotting. In man the bite is very painful, and causes intense local reaction. The victim may apparently get over the immediate effects of the bite, and several hours may elapse before anything further happens. Then there may be uncontrollable

hæmorrhage from the wound and mucous membranes, and severe abdominal cramp. The blood is cherry-coloured from solution of the red cells, and there is heavy albuminuria or hæmaturia. Subsequently the local inflammation turns to phlegmon and spreading gangrene; there is deep and extensive destruction of tissue, which may end fatally in blood-poisoning and general wasting several weeks after the infliction of the bite.

In these Viperine venoms we see to a marked degree: (*a*) the action of those toxins that particularly affect the blood and vascular system; (*b*) sudden onset of symptoms; and (*c*) liability to extensive gangrenous destruction of tissues locally, if the victim survive the first effects of the bite.

(*c*) *Effects of the Venom of Australian Elapines.*—According to Dr. Martin, the local pain and swelling are not severe, and from fifteen minutes to two hours after being bitten the victim becomes faint and lethargic. He staggers and cannot stand. Alarming symptoms of shock follow, often with vomiting, the pulse becoming thread-like, and the extremities cold. The victim becomes comatose, with dilated pupils insensitive to light. Respiration becomes shallower, and may cease; or the patient may rapidly recover. In some cases there is bleeding from the mucous membranes. Albuminuria has generally been found when looked for. The heart may sometimes be felt for a few seconds after breathing has ceased.

In the venoms of the Australian Elapines the effects of both classes of toxins—those that act on nerve-cells, and those that act on the blood and circulatory system—are manifest.

(*d*) *Effects of the Venom of Hydrophinæ, or Sea-snakes.*—In Fayrer's classical experiments the symptoms observed in animals bitten by sea-snakes much resembled those following cobra bite. The bite was scarcely perceptible, and caused no local reaction. Death, which was rapid after the onset of the symptoms, was preceded by

lethargy, paralysis, unconsciousness, and respiratory convulsions. The blood coagulates firmly after death. All observers agree that the venom of certain sea-snakes is of peculiar virulence. Major Leonard Rogers, who has worked a good deal with the venom of certain sea-snakes, emphasizes the facts that this venom is neurotoxic like cobra-venom, but is many times more potent, that there is a considerable latent period before any symptoms are manifested, and that there is no appreciable action on the blood.

(*c*) *Effects of the Venom of Rattlesnake* (*Crotalinæ*).—The symptoms and sequelæ in a case of bite by a rattlesnake are in many ways similar to those caused by Viperine venom. The general symptoms are rapid in onset, and are marked by syncope and alarming collapse, which may end in death or may be followed by very rapid recovery. Locally there is severe pain and extensive swelling and extravasation, which may go on to spreading gangrene, and a lingering death from septicæmia. The sudden and alarming prostration appears to be due to specific toxins acting directly on the vaso-motor system and heart, which are more abundant in rattlesnake-venom than in other venoms.

The action of the venom of certain other notorious snakes will be referred to in the section dealing with the distribution of Thanatophidia. For the present this subject may be left with a repetition of the caution that a bite—even an untreated bite—from a snake known to belong to a powerfully venomous species is not by any means *necessarily* fatal to man. A bite from such a snake is dangerous only if the animal be in a good condition, with its glands full of venom, and if it take firm hold with its teeth, so as to bite home and inject a lethal charge of the poison. Conversely, these considerations suggest that it must be unsafe to make generalizations as to the virulence of an unstudied species from the effects of a single chance bite ; trustworthy information is to be gained chiefly by a series of experiments with known quantities of extracted venom.

§ 3. Treatment of Snake-bite.

(1) *Theory of Treatment.*—With regard to this subject a few words on immunity, natural and acquired, are necessary as a preface.

It has been settled by experiment not only that a venomous snake is normally tolerant of the poison of its own species, and in some cases at least of that of other species, but also that some of the harmless Colubrines show resistance—or even complete immunity—to snake-venom. Thus two South American Opisthoglyphes, namely, *Erythrolamprus æsculapii* and *Rhachidelus brazili*, are said to be completely indifferent to the venom of the various poisonous snakes that form their habitual food; and an American Aglyphe, *Coronella getula*, which overpowers and devours rattlesnakes, is said to be immune to the venom of its prey. Furthermore, and quite apart from myth, there are mammals—among them, in particular, the mongoose, the hedgehog, and the pig—that are known to possess some tolerance of snake-venom.

Acquired immunity to snake-venom is also known. Not only in the mystic circle of snake-charmers, but outside it, there have been men who have accustomed themselves to the poison of a particular species of snake by the simple process of inoculation with a very small dose followed by a series of doses of gradually increasing strength. Sewall demonstrated, in 1887, that pigeons could be immunized in this way to the venom of the rattlesnake; and between 1892 and 1894 Calmette was successful in working horses up to such a degree of tolerance of cobra-venom that at last they were able to stand, at a single injection, a dose of venom estimated by him to be strong enough to kill eighty uninured horses. The serum of horses so immunized to cobra-venom was proved by Calmette to have antitoxic powers. Calmette believed at first that it was antitoxic to *all* venoms, but it has since been shown, particularly by the experiments of Martin, Lamb, and Rogers, that this is

not the case, and that it is *completely* antagonistic only to the *specific* venom by which it is elicited, namely cobra-venom. Calmette's horse-serum, defibrinated and filtered with aseptic precautions, and portioned out in sterilized bottles of 10 c.c. capacity, is what is commonly known as antivenine.

The antivenomous sera, or antivenines, originated by Calmette, or modifications of them, are now prepared and issued with directions for use by institutions in several countries. In the discussion of treatment they must take precedence of everything, not because they are, at the present moment, by any means perfectly assured and adapted to universal practice, but because they are based upon principles that are entirely rational, and that promise unimpeachable therapeutic results in the future.

Considered to begin with merely as instruments : quite aside from difficulties of preparation, which are great and manifold, and apart from their possible instability under ordinary tropical conditions, they are weak. To illustrate this point Martin and Lamb make a very striking comparison between the antitoxins of diphtheria and tetanus on the one hand, and antivenom on the other, showing that volume for volume by respective standard antivenom has only one-ten-thousandth the specific neutralizing value of the first, and only one-twenty-thousandth that of the second. This, as they insist, involves the employment of very large volumes of antivenom—more than 100 c.c. for an intravenous injection, and very much more for a subcutaneous injection—if all the venom that may be absorbed from a bite is to be neutralized. But Calmette, whose idea seems to be not to neutralize or satisfy all the venom that may be injected by a snake, but to "augment the natural resistance" of the tissues, brings forward a good deal of evidence, of a sort, to justify his contention that in cases of cobra-bite a hypodermic injection of 10 or 20 c.c. of his antivenom is enough "to cure human beings."

Next, to consider antivenoms as remedial agents: There is a consensus of expert opinion that each is *specific*, that is to say, is fully potent only against its corresponding venom, and is more or less impotent against other venoms, just as a specific bacterial antitoxin is active only against its corresponding microbe. From this point of view, which is well supported by experiment both *in vitro* and and *in vivo*, it follows that the employment of antivenom is conditioned in one of two directions. Either (1) we must capture and identify in every case the snake that inflicted the bite, and must have at hand the corresponding antivenom; or (2) without stopping to consider the snake, we must have at our disposal a synthetic (multivalent) antivenom—a serum that has been rendered immune to all the common species of Thanatophidia of the country served. Neither of these conditions is at present fulfilled: the first is obviously a condition of unattainable perfection—is outside the possibilities of experience and practice; there is good hope that the second may be fulfilled, indeed, something is now being done towards its fulfilment in some countries.

Coming now to the possible use of antivenines at the present moment: if the *specific* antivenom for the snake that has inflicted the bite is at hand, it should be injected as soon as possible. If the *specific* antivenom is not available, then in dealing with a case of bite by any Viperid, or by an Australian Elapine, nothing is to be hoped from an injection of cobra antivenine; but if it be a case of bite by any of the other alien Elapines, then there can at least be no objection to the use of cobra antivenine. The procedure may not be entirely rational *a priori*, but, in the present state of our knowledge, it is at least a legitimate experiment, based on a hope of "increasing the natural resistance" of the patient, and of *retarding* the action of the alien venom. Leonard Rogers's experiments, though they helped to establish the view that Calmette's cobra-antivenom is *fully* potent only against cobra-venom, make it clear that

it has a retarding effect, and also some limited neutralizing power upon the neurotoxins of other Indian Colubrines as well as of certain sea-snakes. All competent observers agree, however, that Calmette's antivenom is of no avail at all against the venom of the *Viperidæ*.

(2) *Practical Treatment of Snake-bite.*—Whether a reliable antivenom—synthetic or specific—is available or not, energetic local treatment is always obligatory, the indications being to prevent or delay absorption of venom, to attempt to destroy the venom locally, and to assist its elimination.

To prevent or delay absorption, a ligature should be applied as soon as possible, or two ligatures, one a good deal higher than the other. The ligature must be twisted, in the words of Sir Joseph Fayrer, "without mercy," but it must not be kept on longer than is necessary to accomplish thoroughly the next steps in the treatment.

The knife must now be freely used. It must be remembered that the fangs may have been driven in deep, that the venom is injected with force, and that the fine interstices of the areolar tissue exercise capillary attraction, so that the venom may have travelled far from the points of puncture. For these reasons it is a vital matter to make long and deep cuts, to lay the wounds well open, and to let the blood flow and perhaps carry away some of the venom that has lodged.

With the object of destroying the venom the wounds should be thoroughly well washed out with some of the reagents that are known to render venoms inert *in vitro*. Calmette recommends a 2 per cent. solution of hypochlorite of lime, or a $\frac{1}{10}$ per cent. solution of gold chloride; but the best for many reasons is the *strong solution of permanganate of potash* advocated by the British school.

If suitable antivenom is at hand it should be used as soon as possible to neutralize the venom that has been absorbed. Martin and Lamb insist that, of antivenoms at present obtainable, at least 100 c.c. should be injected,

with due precautions, into a vein. Calmette prefers injection under the skin of the flank, and considers that a dose of 10 c.c., followed, if necessary, by a second, is enough. After the injection the patient must be kept warm and at rest. According to Calmette, strong stimulants are not only useless but actually interfere with the action of the antivenom.

If no suitable antivenom is at hand, then, after local measures have been carried out efficiently, the case can only be treated on general principles. The patient must be kept at rest and kept warm, and, when possible, warm drinks should be given to excite perspiration. Alcohol in small doses, and ammonia, may be given as stimulants; but enormous doses of alcohol are likely to be hurtful, as they tend to paralyse the vaso-motor control. Strychnine is always useful, both as a respiratory stimulant and to raise fallen blood-pressure. Sir Lauder Brunton has suggested nicotine, and Leonard Rogers adrenalin, to raise the blood-pressure. In cases of Colubrine poisoning artificial respiration should be resorted to if necessary; and for the hæmorrhage of the latter stages of Viperine poisoning several officers of the Indian Medical Service have lately used adrenalin with success. In cases of viperine poisoning, that have not been immediately fatal, precautionary measures should be taken against septicæmia, from the rapid and extensive sloughing that is very likely to occur. Several observers, it may be mentioned, consider that this sloughing is due to the destruction by the venom of the normal germicidal power of the blood.

§ 4. Genera and Species of Venomous Snakes and their Geographical Distribution.

We have to consider (1) the Proteroglyphe *Colubridæ* with two sub-families, *Hydrophinæ* and *Elapinæ;* and (2) the *Viperidæ*, also with two sub-families, *Viperinæ* and *Crotalinæ*. The characters that differentiate *Colubridæ*

and *Viperidæ* from all other snakes, and from each other, have already been considered (p. 234).

[It must not be forgotten, however, that although we are not at present in a position to deal with the matter succinctly, the bite of the Opisthoglyphe *Colubridæ* is *suspicious*, and that there is at least one well-authenticated case of a bite from one of the Opisthoglyphes proving extremely serious to a healthy European. The case in question has been reported by Mr. F. W. Fitz-Simons, and the Opisthoglyphe in question is *Dispholidus typus*, a large South African species known locally as the "boomslang." An hour after being bitten the victim complained of throbbing headache, and began to vomit. Shortly afterwards blood began to ooze from the bite, and from the nose, mouth, bladder, and bowels, and also to extravasate under the skin in large patches in several parts of the body. The victim lingered between life and death for several days, and did not completely recover until the end of three weeks. Some fowls bitten by large "boomslangs," as a sort of control experiment, died within twenty minutes. The "boomslang" is a large tree-snake with a long tail; the head is distinct from the neck, the snout is short, and the eye is very large with a round pupil; the scales are oblique, very narrow, and keeled, and there are nineteen to twenty-one in a transverse row; the ventral shields are either rounded or obtusely angulate at the sides, and the sub-caudals are in two rows. The maxilla is short and *carries seven or eight small teeth*, followed by three very large grooved fangs; the *transpalatine bone is forked anteriorly*. The colour is very variable, brown or olive or green above, yellowish or greyish below; the scales and shields sometimes have dark edges, and the head may be speckled with black and the belly with brown; or the colour may be black above, each scale having a yellowish or greenish spot. The head of this species is shown in fig. 106.]

The position of the *Colubridæ* and *Viperidæ* in the order of Ophidia is shown in the following table, which, as well

as the succeeding tables, is based upon those published in Mr. G. A. Boulenger's classical "Catalogue of Snakes in the British Museum."

SYNOPSIS OF FAMILIES OF SNAKES.

1	Body covered in every part with hard, shiny, imbricating, "cycloid" scales of uniform size; eyes minute, lying beneath the head-shields; coronoid present; no transpalatine or squamosal bones. Worm-like snakes, living under ground	2
	Scales and eyes normal; transpalatine bone present (cp. figs. 95 and 96, *tr.*)	3
2	Maxilla transverse, with a few teeth; mandible toothless	*Typhlopidæ.*
	Maxilla toothless; mandible with teeth	*Glauconiidæ.*
3	Coronoid bone present (fig. 97, *cor.*); ventral shields either of moderate size or quite small	4
	Coronoid bone absent; ventral shields, *except in some aquatic species*, large	5
4	No squamosal bone; ventral shields small. Burrowing snakes restricted to the hills of Peninsular India and Ceylon	*Uropeltidæ.*
	Squamosal bone present (cp. fig. 95, *sq.*); concealed vestiges of hind-limbs present	6
6	Squamosal large; ventral shields usually of fair size	*Boiidæ.*
	Squamosal small; ventral shields extremely small	*Ilysiidæ.*
	(S.E. Asia and Tropical S. America.)	
5	Maxilla horizontal	7
	Maxilla short, not horizontal, vertically erectile	*Viperidæ.*
7	Pterygoid bone reaching quadrate or mandible (fig. 95, *pt.*); a mental groove (fig. 94, *m.g.*)	8
	Pterygoid bone not reaching quadrate or mandible; no mental groove	*Amblycephalidæ.*
	(S.E. Asia and Tropical S. America.)	
8	Teeth in premaxilla; ventral shields not extending completely across the belly	*Xenopeltidæ.* (S.E. Asia.)
	No teeth in premaxilla (fig. 96, *p.m.*); ventral shields stretching right across the belly in almost all the species that *live on land*	*Colubridæ.*

Colubridæ	(i) None of the maxillary teeth grooved (harmless)	*Aglypha.*
	(ii) Some of the posterior maxillary teeth enlarged and grooved (suspicious)	*Opisthoglypha.*
	(iii) Front tooth in the maxilla enlarged and canaliculate (venomous)	*Proteroglypha.*

A. Synopsis of Proteroglyphe Colubridæ.

Tail strongly compressed paddle-like. Sea-snakes *Hydrophinæ.*
Tail cylindrical. Land-snakes ..... *Elapinæ.*

(*a*) Synopsis of Genera of Hydrophinæ.

The differences that separate some of the genera are so slight that only the more important and more remarkable genera need be considered.

Ventral shields large 1
Ventral shields small or altogether undifferentiated 2

1 — Nostrils on top of the snout (as usual in the subfamily) ..... *Æpysurus.* (Java to New Caledonia.)
1 — Nostrils lateral (as in most land-snakes) ..... *Platurus.* (India to Fiji and New Zealand.)

2 — Mental shield (fig. 94, *m*) triangular, not at all concealed in a groove 3
2 — Mental shield narrow, partly concealed in a deep groove in the chin ..... *Enhydrina.* (Persian Gulf to New Guinea.)

3 — No differentiated ventral shields 4
3 — Small ventral shields present, at least in part of the body 5

4 — Lateral scales of the lower rows enlarged..... *Enhydris.* (Bay of Bengal to New Guinea and China.)
4 — Lateral scales of the lower rows not enlarged ... *Hydrus.* (E. Africa to Panama.)

5 — Only the poison-fangs are grooved..... *Hydrophis.* (Persian Gulf to N. Australia and China.)
5 — All the maxillary teeth, and sometimes also the anterior mandibular teeth, are grooved ..... *Distira.* (Persian Gulf to Japan and New Caledonia.)

(*b*) Synopsis of Genera of Elapinæ.

For convenience sake, and as there is only one genus (namely, *Naja*, that to which the cobras belong) that is common to two continents, the genera are here tabulated geographically.

I. African Elapinæ.

Tail more than one-seventh the total length..... 1
Tail less than one-ninth the total length 2

1 — Maxilla of ordinary form 3
1 — Maxilla curved upwards, with a strong spur at its posterior end (fig. 104*b*) ..... *Dendraspis.*

3 — Scales disposed very obliquely 4
3 — Scales not remarkably oblique 5

4 — Scales smooth..... *Naja.*
4 — Scales strongly keeled ..... *Sepedon.*

5 { No teeth in the maxilla except the poison-fangs; tail short ..... *Walterinnesia.*
  { Three or four teeth in the maxilla besides the poison-fangs; tail long ..... *Boulengeria.*

2 { Rostral shield normal 6
  { Rostral shield very large, detached at the sides *Aspidelaps.*

6 { Poison-fangs grooved as usual; no longitudinal vertebral stripe ..... *Elapechis.*
  { Poison-fangs not grooved; often a bright longitudinal vertebral stripe ..... *Homorelaps.*

II. Asiatic Elapinæ.

1 { A row of enlarged scales along the middle line of the back (fig. 104*c*) ..... *Bungarus.*
  { No mid-dorsal line of enlarged scales 2

2 { Large snakes, not brilliantly coloured; neck dilatable ..... *Naja.*
  { Long slender snakes, often with stripes or bands, and usually showing some red in their colouring; neck not dilatable 3

3 { From one to three small teeth in the maxilla behind the poison-fangs ..... *Hemibungarus.*
  { No teeth in the maxilla except the poison-fangs 4

4 { Poison-gland situated in the temporal region as usual ..... *Callophis.*
  { Poison-gland having the form of a long slender cord extending far along the body ..... *Doliophis.*

III. Australian Elapinæ.

The Australian genera are so numerous, and are separated by such slight differences, that it is impossible here to tabulate any that are not of striking appearance or of known practical importance.

Viper-like snakes 1
Not viper-like in appearance 2

1 { Scales smooth; subcaudal shields in a single row ..... *Brachyaspis.*
  { Scales of the back keeled; posterior subcaudal shields in two rows; tail ending in a sort of spine ..... *Acanthophis.*

2 { Rostral shield of ordinary size and form 3
  { Rostral shield very large, detached on the sides *Rhinoplocephalus.*

3 { Ventral shields of the ordinary curved form 4
  { Ventral shields laterally angulate and notched *Hoplocephalus.*

4 { Scales smooth 5
  { Scales strongly keeled ..... *Tropidechis.*

4 { Poison-fangs followed, at a distance, by from 7 to 15 small grooved teeth ..... *Diemenia.*
  { Poison-fangs followed, at a distance, by from 1 to 5 small teeth which may be indistinctly grooved 6

6 { Subcaudal shields in two rows, at any rate in the posterior part of the tail ..... *Pseudechis.*
Subcaudal shields in a single row 7

7 { Scales disposed very obliquely..... *Notechis.*
Scales not remarkably oblique..... *Denisonia.*

IV. American Elapinæ.

The American Elapines all belong to the one genus, *Elaps*, which is restricted to America and includes about thirty species.

The species of *Elaps* are generally brilliantly coloured, in rings. The maxilla is very short and has no teeth but the large poison-fangs. The head and eye are small, and there is no distinct neck. There is no loreal shield. The scales are smooth and number fifteen in a transverse row. The tail is short and the sub-caudal shields are in two rows in all or part of its extent.

B. Synopsis of Viperidæ.

A sensory pit (loreal pit) between the eye and the nostril (fig. 105, *i*) ..... *Crotalinæ.*
No loreal pit..... *Viperinæ.*

(*a*) Synopsis of Genera of Viperinæ.

Crown of the head with large symmetrical shields like a Colubrine (cp. fig. 104, *e*) 1
Crown of the head with small scales only, or with small scales and some small shields..... 2

1 { Numerous teeth in the mandible; loreal shield present 3
Only two or three teeth in the mandible: no loreal shield (fig. 107)..... *Atractaspis.* (Africa, Arabia and Persia.)

3 { Pupil round; scales on the sides of the body very oblique ..... *Causus.* (Africa.)
Lateral scales not particularly oblique ..... *Azemiops.* (Upper Burma.)

2 { Scales on the sides *not* smaller than those on the backs, their keels sharp, *i.e.*, not serrated (cp. fig. 102, *e*, *f*) 4
Scales on the sides smaller than those on the back 5

4 { Ventral shields of the ordinary curved form..... 6
Ventral shields with a keel on either side..... *Eristicophis.* (Baluchistan.)

6 { Nasal shield either touching the rostral shield or separated by a naso-rostral shield..... *Vipera.* (Europe, Asia and Africa.)
Nasal shield separated from the rostral shield by small scales (fig. 104, *h*) 7

7 { A semilunar supra-nasal shield (fig. 104, *h*) ..... *Bitis.* (Africa and Arabia.)
No supra-nasal shield ..... *Pseudocerastes.* (Persia and Baluchistan.)

5 { Scales on the sides of the body with sharp keels; tail from about one-sixth to about one-fourth the total length ..... *Atheris.* (Africa.)
Scales on the sides of the body with serrated keels (fig. 102, *a*—*d*); tail short 8

8 { Ventral shields of the ordinary curved form..... *Echis.* (Asia and Africa.)
Ventral shields with a keel on either side (fig. 103) *Cerastes.* (Africa, Arabia and Syria.)

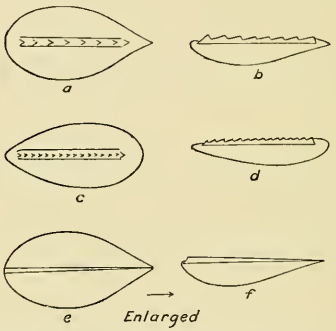


FIG. 102.—Lateral scales, *a*, *b*, *Echis*—serrated keel, surface and profile; *c*, *d*, *Cerastes*—serrated keel, surface and profile; *e*, *f*, *Bitis*—sharp keel, surface and profile.

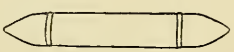


FIG. 103.—Ventral shield of *Cerastes*, showing lateral ridges.

(*b*) SYNOPSIS OF GENERA OF CROTALINÆ.

Tail ending in a rattle (Rattlesnakes) 1
Tail not ending in a rattle (ordinary loreal-pit-vipers)..... 2

1 { Head with large symmetrical shields. Small, slender snakes..... *Sistrurus.* (N. America.)
Head with small scales alone, or with small scales and some small shields. Large bloated snakes as a rule ..... *Crotalus.* (N. and S. America.)

2 { Head with large symmetrical shields (fig. 104, *g*) *Ancistrodon.* (Asia and America.)
Head with small scales alone, or with small scales and some small shields ..... *Lachesis.* (Asia and America.)

THE THANATOPHIDIA OF EUROPE all belong to the one genus, *Vipera;* five European species are known, of which only two are peculiar to Europe. Most of the species are speckled and have a dark V-shaped mark on the crown, a dark oblique bar behind the eye, a zigzag or wavy stripe along the back, and a series of dark lateral spots. In some of the species the tip of the snout is turned up, and may form a sort of horn. Vipers as a rule prefer dry, sandy, or rocky country, where they can bask in the sun; but they may be found anywhere, even in marsh-land, and they will take to water. The common viper (*V. berus*) is responsible for a good many bites, a small percentage of which are fatal. The action of the venom is said to be, both locally and generally, like that of rattlesnake venom, but not so severe.

THE THANATOPHIDIA OF ASIA are peculiar in including numerous examples of all four sub-families. The number of species, exclusive of sea-snakes, is more than sixty.

The Asiatic *Elapinæ* belong to the following genera:—

(*a*) *Naja.*—In this genus, which is also represented in Africa, the eye is of fair size, the scales are smooth and are disposed obliquely; and in all the Asiatic species the neck can be dilated under excitement to form a "hood." (1) *Naja tripudians*, the common Asiatic cobra, is a familiar snake all over Southern Asia. Its colour varies from dingy yellow to black, uniform or banded, and on the hood there is often a "pair of spectacles," or a large "eye," or a U-shaped mark. It may grow to a length of 6 ft. It is very commonly met with in houses and gardens and among neglected buildings, and is proverbially a fatal snake. (2) *Naja bungarus*, the "king cobra," or hamadryad, is distinguished by its superior size, and by the possession of a pair of large occipital shields

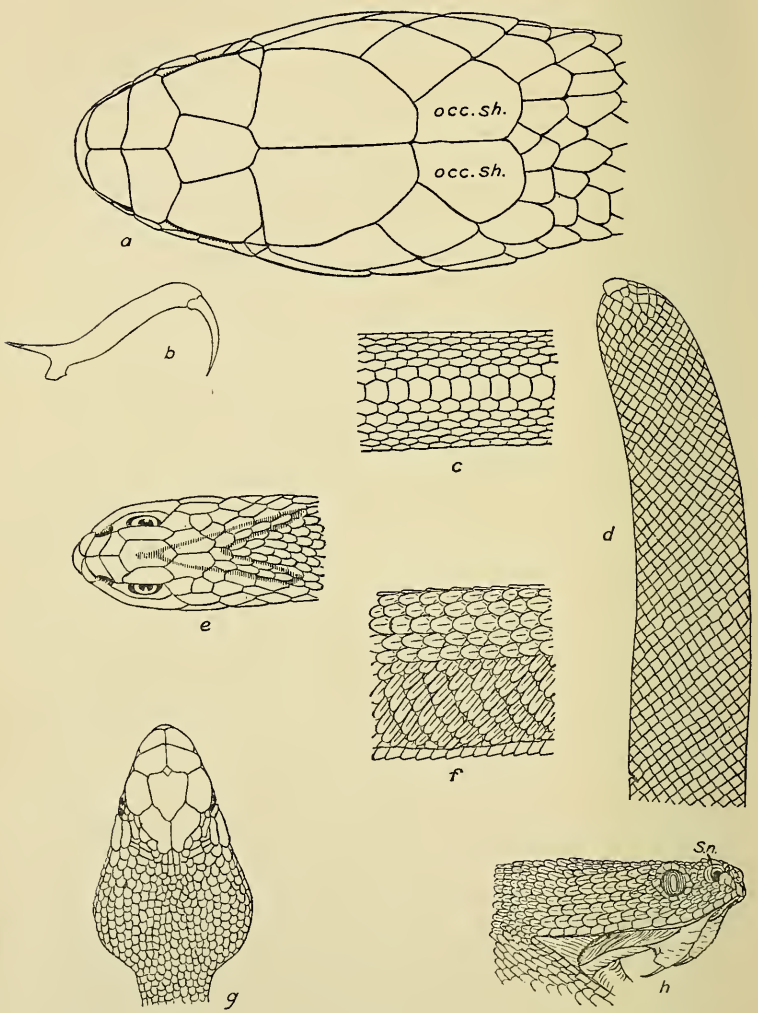


FIG. 104.—*a*, head of *Naja bungarus*, showing occipital shields; *b*, maxilla of *Dendraspis*; *c*, *Bungarus candidus*, showing enlarged vertebral scales; *d*, laterally compressed tail of sea-snake; *e*, head of *Causus rhombeatus*, showing large shields; *f*, *Cerastes*, showing oblique lateral scales; *g*, head of *Ancistrodon*, showing large shields; *h*, head of *Bitis*, showing supra-nasal shield and small scales between nasal and rostral shields.

It is a notoriously fierce and aggressive snake. Its colour varies from dull yellow to bluish-black, uniform or cross-banded. It is fairly common, chiefly in jungle tracts, in India and the countries to the east, and in the Malay Archipelago, but it is not met with in dwellings. It may attain a length of about 14 ft., and individuals 12 ft. long are not at all rare. Its venom is of equal potency with cobra-venom, and has the same neurotoxic action, especially on the respiratory centre, but it has hardly any effect on the blood. According to Rogers, Calmette's antivenom has a distinct retarding effect upon this venom.

(*b*) *Bungarus*.—The species of this genus, known as Kraits, number about half a dozen, and are restricted to Asia. They can be recognized by the row of enlarged scales of the mid-dorsal line, and by their small poison-fangs. The two commonest species are *Bungarus candidus* (=*cæruleus*) and *Bungarus fasciatus*. (1) *B. candidus* or *cæruleus*, the common krait, is a slender snake, usually between 2 and 3 ft. long, but occasionally attaining a length of 4 ft. Its colour varies from bluish-black to purplish-brown, and the body is generally marked with narrow white rings, entire or broken; there is sometimes a series of large white spots along the mid-dorsal line. The common krait is found all over Southern Asia, east of Baluchistan, and in the Malay Archipelago. It is very often met with in gardens and dwellings, but is shy and timid. Its venom seems, except that it has less hæmolytic action, to be identical in action with cobra-venom, but is estimated to be about four times as virulent. (2) *B. fasciatus*, the banded krait, is distinguished by its sharply ridged back, and short, blunt tail. It is conspicuously coloured in broad alternating cross-bands of bright yellow and blue-black. It is a stoutish snake, and may attain a length of 5 ft. or more. Its geographical range is the same as that of the common krait, and it also gets into houses. According to Leonard Rogers, its poison acts like that of the cobra, but less powerfully, and also contains, like that of some of the Australian Elapines, a

"viperine element," which in large doses may cause intravascular clotting, though it has no hæmolytic property.

(*c*) *Hemibungarus.*—This genus includes slender, brilliant snakes, with a good deal of red in their colouring. One species occurs in the hills of Southern India, the other three belong to the tropical Asiatic islands of the Pacific.

(*d*) *Callophis* in form and colouring resembles *Hemibungarus*. The species, five in number, are distributed in the Eastern Himalayas and Indo-China, and in the hills of Southern India and the Malay Peninsula.

(*e*) *Doliophis.*—The species of this genus differ from *Callophis* only in having very greatly elongate poison glands. They are found in Burma, Indo-China, and the Malay Peninsula and islands.

The genera and principal species of Asiatic *Viperinæ* are the following :—

(*a*) *Vipera.*—The head is broad, and is covered either with small scales alone (Indian species), or with scales and some small shields; the neck is narrow; the eye is separated from the labial shields by small scales, and the pupil is vertical. The nasal shield is either in contact with the rostral shield, or is separated by a naso-rostral shield. The keels of the scales have a sharp, entire edge; the ventral shields are simple. The tail is short, with the sub-caudal shields in two rows. True vipers are found over the greater part of Asia; the most notorious species is *Vipera russellii*, which occurs all over India, from the Himalayas to Ceylon, also in Burma, Siam, and Sumatra. *V. russellii*, the Daboia or Tic Polonga, is a snake of considerable girth, and may attain a length of $5\frac{1}{2}$ ft. It is surly and sluggish, but is fierce when disturbed. It is bright reddish-brown in colour, with three longitudinal series of large, black, white-edged ovals or rhombs; the belly is light, and often spotted with black. It is a dangerous snake, its venom being powerful and causing intravascular clotting in large doses, and active hæmolysis when absorbed slowly. It is a snake that is often found near dwelling-houses.

(*b*) *Echis* differs from *Vipera* chiefly in having *serrated* keels on the scales of the sides of the body; these scales are also smaller than those of the back, and they point downwards. The sub-caudal shields are in a single row. Two species of this genus are known, namely, *Echis carinatus* and *Echis coloratus*. (1) *E. carinatus*, the *Phoorsa* or *Kupper*, is a small snake of a most angry and fierce disposition. Its colour is greyish- or reddish-brown, with one or more longitudinal series of white, dark-edged spots, or sometimes with a white, wavy stripe along either side; there is often a white cross or "broad-arrow" on the head; the belly is white, usually with dark speckles. Besides having an extended range in Northern Africa, it is found in desert tracts all over South-western Asia, from Arabia and Persia to Cape Comorin, occurring in hundreds in certain places. It is a snake of deserts and rocky places, and is likely to turn up in tents and on camping-grounds. Its venom is very active, in the same way as that of Russell's viper. (2) *E. coloratus* is found in Arabia, Syria (and Egypt).

(*c*) *Pseudocerastes* chiefly differs from *Vipera* in having a series of small scales between the nasal and rostral shields. One species is found in Persia and Baluchistan; it has a scaly tubercle above either eye.

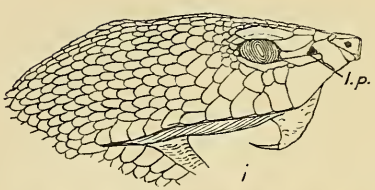
(*d*) *Eristicophis* is another desert snake, differing from *Vipera* chiefly in having a sharp keel or ridge on either side of the ventral shields. One species is known from Baluchistan.

(*e*) *Azemiops* has a head like a harmless Colubrine, covered with large symmetrical shields, and furnished with a loreal shield. One species is known from the hills of Upper Burma.

Other *Viperinæ* which extend into South-western Asia are the African genera (see below), *Bitis*, *Cerastes*, and *Atracaspis*.

The Asiatic *Crotalinæ*, or loreal-pit-vipers, belong to the following genera:—

(*a*) *Ancistrodon*.—Though the head is shaped like that



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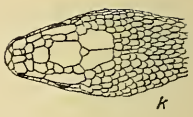

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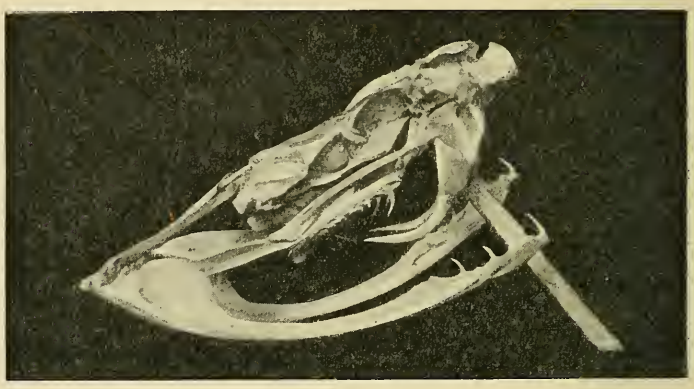

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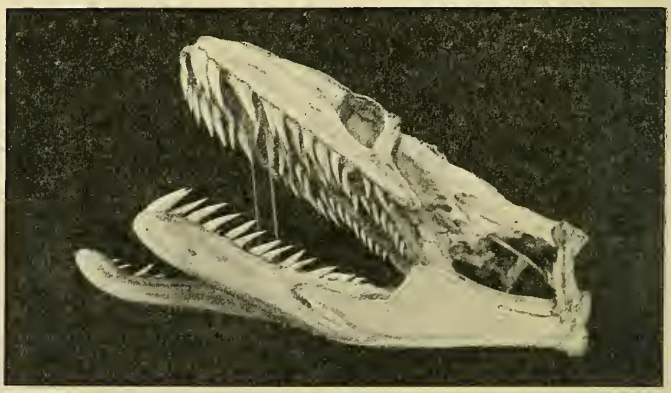

m

FIG. 105.—*i*, Head of *Lachesis*, showing loreal pit (*l. p.*); *k*, head of *Vipera berus*, showing shields and scales; *l*, skull of *Crotalus*, showing oblique maxilla and long transpalatine; *m*, skull of Python, showing *inter alia* absence of mandibular symphysis.

of a typical viper, it is covered with large symmetrical shields like those of a Colubrine. Eight species are known from the mountains and plateaux of Central Asia, China, and Japan; from the Himalayas up to 10,000 ft., and from the hills of Southern India, Ceylon, and Java. They are jungle-snakes, but in some of the open camping-grounds of the Himalayan routes one might pick up a basketful of *Ancistrodon himalayanus* in a morning.

(*b*) *Lachesis*.—The head is truly viper-like, being covered with small scales with sometimes a few small shields. Eighteen species are known from the jungles of South-eastern Asia, from the Himalayas and Southern China, to Southern India and the Malay Archipelago. The venom of *Lachesis gramineus*, a green Indian species, is estimated by Lamb to be only about one-fortieth as potent as that of *Echis*.

THE THANATOPHIDIA OF AFRICA number about sixty species, and all, except a sea-snake (*Hydrus platurus*) that occurs in Madagascar, are *Elapinæ* and *Viperinæ*.

The following are the genera of African *Elapinæ* :—

(*a*) *Naja*.—(1) *Naja haje* is a species of North-eastern Africa, distinguished by having the eye completely separated from the labial shields by small sub-ocular shields. It is a dingy coloured snake. (2) *Naja flava* is a South African species, in which the third and fourth upper labials are in contact with the eye. (3) *Naja melanolenca* is found all over Tropical Africa, and attains a length of 8 ft. It differs from *N. flava* in having yellowish cheeks with broad, black posterior borders to the labial shields. (4) *Naja nigricollis* is found all over Central Africa, from about 15° North to about 22° South. It differs from the other three species in the labial shields, of which the third or fourth are the deepest, and the sixth and seventh are not in contact with the post-ocular shields. The three other species of African cobras have a non-dilatable neck (no "hood").

(*b*) *Sepedon* differs chiefly from *Naja* in having the scales strongly keeled. One species, *Sepedon hæmachates*, or

"Rhinghals," is known from South Africa. Sir Thomas Fraser and Dr. Gunn find its venom to be like that of the cobra, but less potent, and with little subsidiary action on the blood.

(*c*) *Dendraspis*.—The species of this genus are known as tree cobras, and are said to be extremely fierce and aggressive. They have a narrow head, and a long, sharpish face, and a most peculiar shape of maxilla (fig. 104, *b*). They are usually of a greenish colour. Their venom requires to be studied.

The other African genera are *Walterinnesia* (one species) from Egypt, *Boulengeria* (one species) in Central Africa, *Aspidelaps* (two species) and *Homorelaps* (two species) from South Africa, and *Elapechis* (six species) from the Gaboon to the Zambesi.

The African *Viperinæ* belong to the following genera:—

(*a*) *Vipera*.—Two species in Northern Africa, namely: (1) *Vipera latastii*, recognized by its turned-up (sometimes horn-like) snout, and (2) *Vipera lebetina*, distinguished by the possession of a supra-nasal shield; and *Vipera superciliaris* from the Mozambique coast, which has neither turned-up snout nor supra-nasal shield.

(*b*) *Bitis*.—This genus differs from *Vipera* (see p. 258) in having above the nostril a pocket covered by a large crescentic supra-nasal shield (fig. 104, *h*), and also in having one or several series of small scales between the nasal and rostral shields. There are eight species, distributed all over the southern part of the continent, from the Niger to the Cape, and from the Gold Coast to the Red Sea, The three best known species are the following: (1) *Bitis arietans*, the Puff-adder, a species that grows to a length of 5 ft., and has a range co-extensive with that of the genus, besides extending into Arabia: it is distinguished by its nostrils, which are directed upwards (not upwards and outwards), and by its colouring, which is yellowish or brown with a series of dark V-shaped bands pointing backwards: there is a dark patch on the crown and another between the orbits, and the two are separated

by a complete or broken yellow line. The bite of the Puff-adder is much dreaded. (2) *Bitis gabonica*, the River Jack Viper, sometimes also called Puff-adder, is a large and wonderfully coloured species, with a pair of coarse, horn-like scales in contact with one another on the snout. Sir H. Johnston describes its colours in life as "a carpet pattern of alternate black, greenish-yellow, mauve, and buff," the black patches being in the mid-dorsal line and shaped like an hour-glass. It has been found in West and East Africa and in Zanzibar. It is said to be sluggish, but a bite from its enormous fangs is regarded as fatal. According to Leonard Rogers its venom produces intra-vascular clotting at first, and subsequently destroys the coagulability of the blood. (3) *Bitis nasicornis* is another large species with "horns" on the snout, but the horns are separated from one another by small scales, and there is more than one pair: the colouring is much like that of *B. gabonica*, but the dark "hour-glass" patches in the mid-dorsal line are completely divided in the middle, and the light patches which separate them are sharply nicked at either end; on the head there is a large, dark "spear-head" mark. *B. nasicornis* occurs in West Africa.

(*c*) *Cerastes* (fig. 104, *f*).—This genus resembles *Echis* in having the lateral scales much smaller than the dorsal scales, directed downwards, and furnished with *serrated* keels; but differs from *Echis* in the form of the ventral shields, which have a sharp ridge at either side (fig. 103), and in having two rows of small, hardly differentiated sub-caudal shields. There are two species, and they are coloured to harmonize with the desert in which they live. *Cerastes cornutus* has a pair of "horns" above the orbits, and is found in North-east Africa (and also in Arabia). *Cerastes vipera* has no supra-orbital horns and occurs in North-east Africa.

(*d*) *Echis* (see p. 259).—Both the Asiatic species of this desert genus extend into Northern Africa, *Echis carinatus* ranging almost to the Atlantic coast.

(*e*) *Atheris*.—In this genus of tree-vipers the tail is long

and prehensile, and the prevailing colour is greenish; the lateral scales are smaller than the dorsals and are more or less oblique, but their keels are not serrated; the ventral shields are not ridged, and the sub-caudals are in a single row. The species, two or three in number, are found in forest, from Liberia to German East Africa.

(*f*) *Causus* (fig. 104, *e*).—In this genus the head, like that of a harmless Colubrine, is oval and is covered with large symmetrical shields, and there is a loreal shield; the pupil is round, and the eye is separated from the labials by small sub-orbital shields. The species are found all over the southern part of Africa, from Sierra Leone and Uganda to the Cape. *Causus rhombeatus* is the commonest and most widely ranging species. Its colour is variable, olive or slaty-brown, either uniform, or, more usually, with a dorsal series of large dark spots or V-shaped bands, and there is commonly a dark V-shaped mark on the crown. Dr. H. E. Arbuckle was the first to observe that its poison-glands are band-shaped, entirely subcutaneous, and about one-fourth the entire length of the animal. He also describes its venom as producing locally great ecchymosis and discoloration, and, constitutionally, drowsiness, muscular weakness, and hæmolysis.

(*g*) *Atracaspis* (fig. 107).—In this also the head is, like that of many Colubrines, not distinct from the neck and covered with large symmetrical shields, but there is no loreal; the eye is minute, and the pupil round, and the third and fourth upper labial shields are usually in contact with the eye. The dentition is peculiar; besides the poison-fangs there are very few teeth at all in the mouth. The numerous species are commonly of a blackish colour aud are found all over the southern part of Africa, from Cape Verde and Somaliland to Cape Colony; two species occur outside Africa, namely, one in Arabia and one in Persia.

The Thanatophidia of America number about seventy species. Except for the widely distributed sea-

snake, *Hydrus platurus*, which has been taken off the Pacific coast of Tropical America, they are all *Elapinæ* and *Crotalinæ*.

American *Elapinæ* all belong to the genus *Elaps* (p. 253), and most of them are vividly coloured in rings. Of the

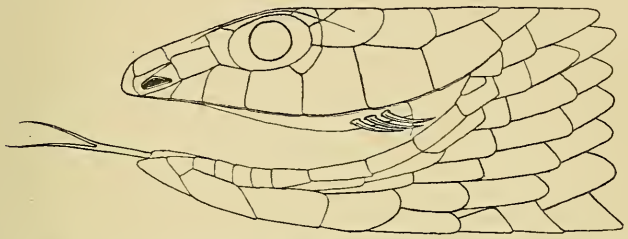

FIG. 106.—*Dispholidus typus*. The Boomslang, showing very wide gape and grooved *posterior* fangs.

thirty species known all but three are South American. *Elaps surinamensis*, the Himeralli, is found in the neighbourhood of rivers and swamps in Tropical South America. It grows to a length of over 6 ft., and is said to be a lethal snake. Its colouring is, like that of several other species,

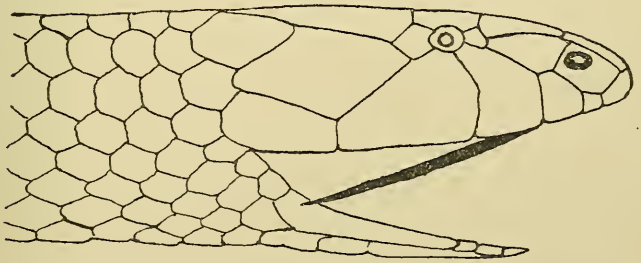

FIG. 107.—*Atractaspis aterrima*. A viperine snake with large headshield, like a Colubrine, prodigious poison fangs, and hardly any other teeth in the head. (Enlarged.)

in black, yellow, and red rings: the black rings are grouped in sets of three, the sets being separated by broad red rings, and the rings in each being separated by narrow yellow rings. *Elaps corallinus* is another

large species whose bite is said to be fatal: it occurs in several of the West Indian islands, and is ringed much like *E. surinamensis*.

American *Crotalinæ*.—America is the headquarters of the sub-family, all the known genera being represented there.

(*a*) *Ancistrodon* (see p. 259).—There are three species, all belonging to North or Central America. (1) *Ancistrodon piscivorus*, the Water-Mocassin or Cotton-mouth, grows to 5 ft., and is found in swamps and brakes—readily taking to water—in Eastern North America. It is distinguished from other American species of the genus by the absence of a loreal shield. (2) *Ancistrodon contortrix*, the Copperhead, has much the same distribution and size as *A. piscivorus*, but it has a loreal shield, and its ground-colouring is yellowish or reddish-brown. The American Ancistrodons are said to be more deadly than rattlesnakes.

(*b*) *Lachesis* (see p. 261).—There are twenty-two species, chiefly South American, and none occurring north of Mexico. They are bush and forest snakes. (1) *Lachesis mutus*, the dreaded Bushmaster, is found from Panama to Bolivia and Brazil, and may attain a length of 14 ft.—8 to 12 ft. being quite common. Its distinguishing marks, besides size, are its narrow supra-ocular shield, and its tail, which ends in a sort of horny spike covered all round with *small scales*. It is said to be extremely fierce. (2) *Lachesis lanceolatus* and (3) *Lachesis atrox*, both known as *Fer de Lance* (*Labarria* in British Guiana, *Jararoca* in Brazil), have a wide range in Tropical America, the former also extending to some of the West Indian islands. Both are distinguished from the Bushmaster by having large supra-ocular shields, and by the tail ending in the ordinary way with sub-caudal shields, not scales, at its tip. The *Fer de Lance* is spoken of as a deadly snake.

(*c*) *Crotalus:* Rattlesnakes.—The Rattlesnakes are well known from the loose rings of hardened epidermis at the end of the tail, the vibrations of which give rise to sound. The head is broad and is covered with small scales alone, or with scales and small shields; the neck is narrow, and

the body is bulky and bloated. Rattlesnakes 5 ft. long are not uncommon, and one species attains a length of 8 ft. The headquarters of the genus are Northern Mexico, but the species are distributed from Canada to Argentina. Rattlesnakes as a rule prefer prairie and rough rocky waste-lands, where they can bask in the sun; but some species are found, at any rate seasonally, in forest, and some of the largest species have a preference for cane-brake and swamp. Rattlesnake venom is markedly hæmolytic, and, quite apart from its action on the blood and vessels, has a direct depressing effect upon the heart.

(*d*) *Sistrurus*.—The small snakes of this genus are known as Pigmy Rattlesnakes and are restricted to North America, from Canada to Mexico: they differ from *Crotalus* in having the head covered with large symmetrical shields, and in their slender make and small size, none of them attaining a length of 3 ft.

The Thanatophidia of Australia, exclusive of the numerous sea-snakes, number between sixty and seventy species and are all *Elapinæ*. The more notorious genera and species are the following:—

(*a*) *Denisonia* (see p. 253).—Over twenty species are known. *Denisonia superba* is the Australian "Copper-head." It is a brownish snake with a yellowish or reddish tinge on the sides: the young have, on the neck, a black blotch or ring which is sometimes edged behind with yellow.

(*b*) *Diemenia*.—In this genus the maxilla is long for an Elapine, and carries, besides the poison-fangs, from seven to fifteen small grooved teeth. Seven species exist, of which *Diemenia textilis*, the "Brown-snake," grows to a length of over 5 ft., and is said to be more deadly than the Indian cobra.

(*c*) *Notechis*.—This genus includes a single species, *Notechis scutatus*, the "Tiger-snake," in which the scales are oblique, those on the sides being somewhat shorter than those on the back. Its colour varies from dull

brown to blackish, the skin between the scales being black. Its venom is estimated to be even more potent than that of the Indian Krait (*Bungarus candidus*), and is said not only to be strongly neurotoxic as well as to have powerful effects on the blood (coagulant and hæmolytic according to dose), but also to have a direct effect upon the heart.

(*d*) *Pseudechis.*—This genus is distinguished from *Notechis* and *Denisonia* by the two rows of subcaudal shields (at least in the posterior part of the tail), and from *Diemenia* by having the maxillary teeth behind the poison-fangs fewer in number and not grooved. There are eight species, one of which, known as the "Black Snake" secretes a venom that is said to be most markedly hæmolytic besides being neurotoxic.

(*e*) *Acanthophis* includes only one species, *Acanthophis antarcticus*, the "Death-adder." It strongly resembles a viper, having a broad head, a narrow neck, a stodgy body, and a short tail. The tail ends in a sort of horny spike. The eye is separated from the labial shields by sub-oculars, and sometimes the supra-ocular shield is raised and horn-like. The venom is estimated to be more virulent than that of the Indian cobra, and is neurotoxic, hæmolytic, and also a vasomotor depressant.

Postcript on Habits of Snakes.—This matter can only be treated very briefly from the "preventive" point of view.

As a rule, to which, of course, there are plenty of exceptions, the snakes that are most likely to be found in and about human habitations are Elapines. The Viperidæ include so many desert-lovers and denizens of the bush and jungle, not a few of them actually showing adaptive modifications to their habitat, that they are not so liable to come in contact with man, except in camp and in tents. Of course there are also some Elapines that are adapted to a particular habitat.

The snakes that are commonly found in dwellings and outhouses in the Tropics, especially where there are thatched roofs, are things like Cobras and Kraits, which

come after rats and mice and small birds and eggs. Russell's Viper and some of the species of *Bitis* will also intrude with the same object.

The sort of place that is likely to harbour such snakes is an old deserted building overgrown with jungle and full of crannies—particularly if there is water near at hand. One can hardly lay down any rules, except that snakes are not likely to be seen in the dwellings of man if compounds are kept free of jungle, long grass, ant-heaps, dilapidated masonry, &c., and if outhouses, fowl-houses, &c., are not too close and are well looked after. But a thatched roof is always suspicious.

While on this subject, it is as well to remember that snakes have certain remorseless enemies, besides those of their own order. In North America a harmless Colubrine, *Coronella getula*, is said to be one of "the most redoubted enemies of the rattlesnake"; and in South America two opisthoglyphe Colubrines, *Erythrolamprus æsculapii* and *Rhachidelus brazili* are said to live exclusively upon venomous snakes. The hedgehog, the mongoose, and the armadillo, owls, kites, and eagles, and various big lizards, also prey upon snakes. Certain birds have got quite a reputation as snake-killers; among them are the secretary-bird of South Africa, the big Australian kingfisher known as the "laughing jackass," and in South America the seriema (*Cariama cristata*), the jaburu stork, and the rhea.

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